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A ROENTGEN STUDY OF THE EVOLUTION OF CARCINOMA OF THE LUNG

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THE STUDY of the evolution or natural development of any disease is not only a fascinating intellectual exercise, a satisfaction of scientific curiosity, but it may contribute enormously to the practical conduct of patients affected by the disease process. The delineation of the natural history of a deep-seated malignant tumor is a difficult problem because the disease commonly does not produce symptoms at its incipiency, so that the presence of the abnormality, in its early stages, may only be discovered fortuitously. Furthermore, when the nature of the process is recognized, we are impelled to introduce some therapeutic mechanism, thus interrupting the natural course of events. In carcinoma of the lung, both of these difficulties are encountered to their fullest extent.

The natural history of carcinoma of the lung cannot be determined at autopsy, which is an end stage, nor by the study of the surgical specimen, which represents only one phase of the lesion's history. There have been studies of untreated cases, followed for various periods of time, but the histories of such cases have been based largely upon the presence of symptoms. The literature is full of data on the duration of life of patients with carcinoma of the lung dated from the onset of symptoms. Most discussions as to the pathogenesis and the development of carcinoma of the lung are, likewise, based largely upon the presence of symptoms.[1, 2, 8, 16] But we know that such data are highly inaccurate because the disease is usually present for long periods

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of time before the onset of any symptoms. Furthermore, it is often impossible to separate the symptoms resulting from the tumor from those accompanying other disease processes commonly found in such patients.

The roentgen examination in carcinoma of the lung presents such a vivid picture, both of the pathology and of the abnormal physiology at the time of the examination, that it is virtually an autopsia-in-vivo. Serial x-ray studies give an admirable picture of the inception, development, and natural progress of the disease. Ordinarily, the roentgen demonstration of a process suggestive of carcinoma will bring about the interruption of its natural course. There are circumstances, however, which permit retrospective study for long periods of time. Errors in the interpretation of roentgenograms in which an abnormality is present, but was either not observed or improperly interpreted, may result in repeated roentgen examinations being made over a considerable period of time without the introduction of any therapy. A smaller group, amenable to such study, consists of those patients who refuse treatment but permit follow-up examinations.

For a number of years we have been doing a backward study of the x-ray findings in histologically proved carcinoma of the lung. Such patients have been closely questioned as to previous x-ray examinations. The frequency with which routine x-ray examination of the chest is now made has enabled us to find a reasonably large number of patients whose previous films could be obtained. In many of these cases there have been serial studies at various intervals. The roentgenograms on which this study is based have been made in a variety of institutions under variable conditions, so that the technique is not always good nor are the intervals between examinations at all consistent. It should be emphasized that these cases have been selected only because of the fact that, fortuitously, a previous roentgenogram of the chest had been made at an interval of more than 3 months before the final diagnosis was established and because it was possible to obtain for examination, the original roentgenograms from the physician or hospital or clinic where they were made. It is obvious at once that only because an error was made in the interpretation of the roentgenograms or in the management of the patient is it possible to make such a study. It is significant that in the approximately 100 such patients carefully studied, all but 2 showed evidences of an abnormality in the area of the lung later proved to be the location of the carcinoma. Furthermore, these x-ray findings have been present in almost all cases long before any significant symptoms were apparent.

In such a study we have used what is commonly called the "retrospectoscope." Looking back with the knowledge that a tumor occurred in a certain area often makes visible and significant a shadow which might otherwise be overlooked. While such retrospective observations may not be entirely indicative of the practical possibilities of roentgen diagnosis, they are perfectly valid indicators of the natural history of the disease.

Within the short time allotted to this presentation, I can only illustrate a few of the great diversity of manifestations which bronchogenic carcinoma

can produce. By means of a number of illustrative cases, I should like to emphasize certain conclusions which have been derived from this study of development.

1. The relatively long duration of carcinoma of the lung has already been reported by us.[14] In this series, it is clear that more than 50 per cent of the cases exhibit roentgen evidences of the disease process more than 2 years prior to either the appearance of symptoms or the determination of a definitive diagnosis.

2. Numerous cases are observed in which the lesion arises as a peripheral process and extends centrally, with late invasion of a major bronchus.

3. During the peripheral stages of the tumor there may be a complete absence of symptoms. The symptoms will then appear shortly after the lesion has extended centrally sufficiently to obstruct or otherwise involve a larger bronchus.

4. In occasional cases the roentgen evidences of bronchial obstruction may be observed before the onset of symptoms.

5. Obstructive emphysema of a whole lobe or even of a whole lung may occur concomitantly with segmental atelectasis.

6. Cavitation may occur very early in the course of peripheral or central lesions and may disappear as the tumor grows.

7. Inflammatory manifestations may appear and disappear during the life of the tumor.

8. There appear to be marked differences in the rapidity of growth of the tumor at various times. Such observations, however, may be more apparent than real as suggested by the studies of Collins and his associates.[3]

9. It is possible to reconstruct the anatomic situation and the development of a tumor of a bronchus when serial roentgenograms of the chest in untreated patients are available and the technique is sufficiently good so that changes in the radiability of the various segments of the lung are visible.

In order to illustrate this method of procedure, a series of cases of varying character are presented.

PERIPHERAL LESIONS

CASE 1.—Squamous-cell carcinoma with some anaplastic elements. A 68-year-old man was first seen by us because of pain in the chest, cough, and a palpable mass of enlarged lymph nodes in the left cervical region. A study of his roentgenologic history indicated that he had been going to a physician for a number of years for routine physical examination. On many occasions, routine roentgenograms of the chest were made, although there were no physical findings nor any symptoms to direct attention to the lungs. A film made in 1951 (Fig. 1, *a*) showed no evidence of abnormality. In 1952, there was no change. An abnormality is first clearly visible in the rontgenogram made in 1953 (Fig. 1, *b*) in which a small lesion in the left upper lobe (arrows) can be clearly made out. This was ignored. A roentgenogram made in 1954 revealed the same lesion, only it was slightly enlarged. In 1955 (Fig. 1, *c*), the lesion is still larger and more apparent. It is notable that throughout this time there were no pulmonary symptoms. In 1956, with symptoms now present for approximately 3 months and with metastasis already apparent in the cervical lymph nodes, the roentgenogram shows a striking enlargement in the process (Fig. 1, *d*), which now extends from apex to below the second rib.

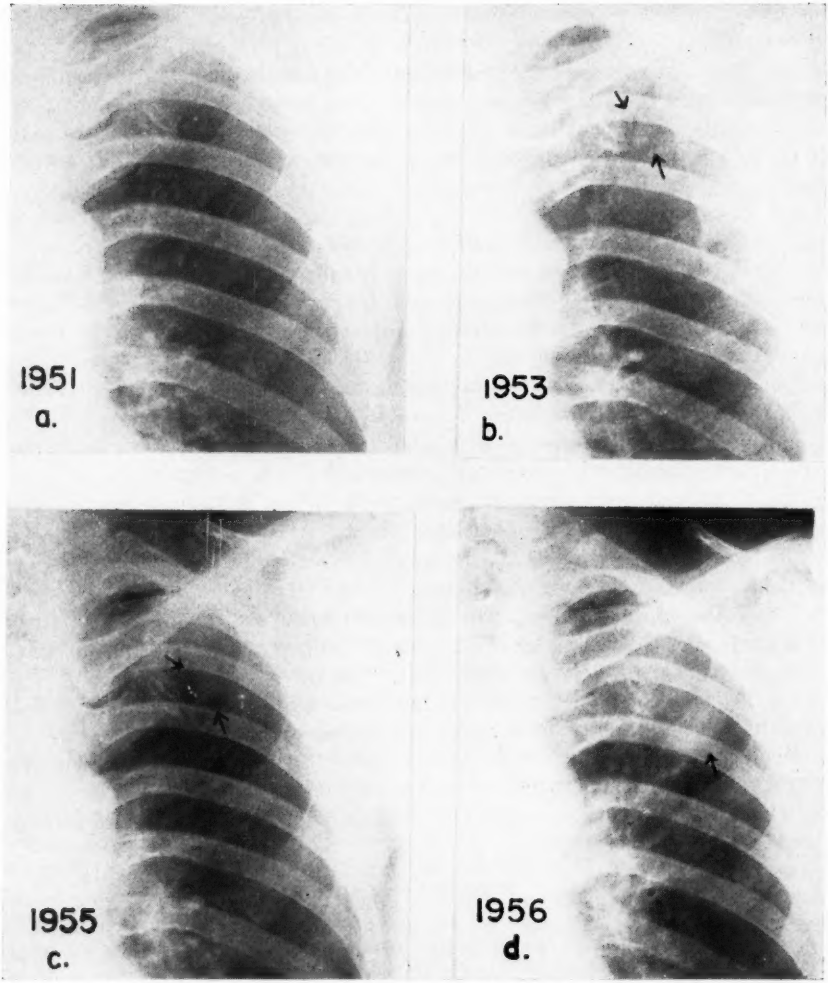

Fig. 1.—Case 1. Carcinoma left upper lobe and peripheral lesion.

a, Segment of roentgenogram of chest made in 1951, no symptoms. No evidence of abnormality.

b, Same area in roentgenogram made in 1953, presymptomatic. Note linear shadow first interspace (arrows), not visible in previous film. Appearance simulates tuberculosis, possibly old scar, or residual of pneumonitis. The recent appearance of such a lesion in a man of 65 should arouse suspicion of carcinoma.

c, Same area in roentgenogram made in 1955, still without symptoms. Note increase in extent and density (arrows).

d, Same area in roentgenogram made in 1956, 3 months after onset of symptoms. Metastasis to cervical lymph nodes already present. Shadow now extends from apex to just below second rib and is much wider mediolaterally.

Proved to be squamous-cell carcinoma with some anaplastic elements.

Comment.—Here is a peripheral lesion giving a shadow which simulates a minimal scar of tuberculosis, increasing slowly in size and extending both peripherally and centrally with obvious metastasis appearing only at the very end. A period of 3 years elapsed from the first time that some evidence of a lesion could have been obtained.

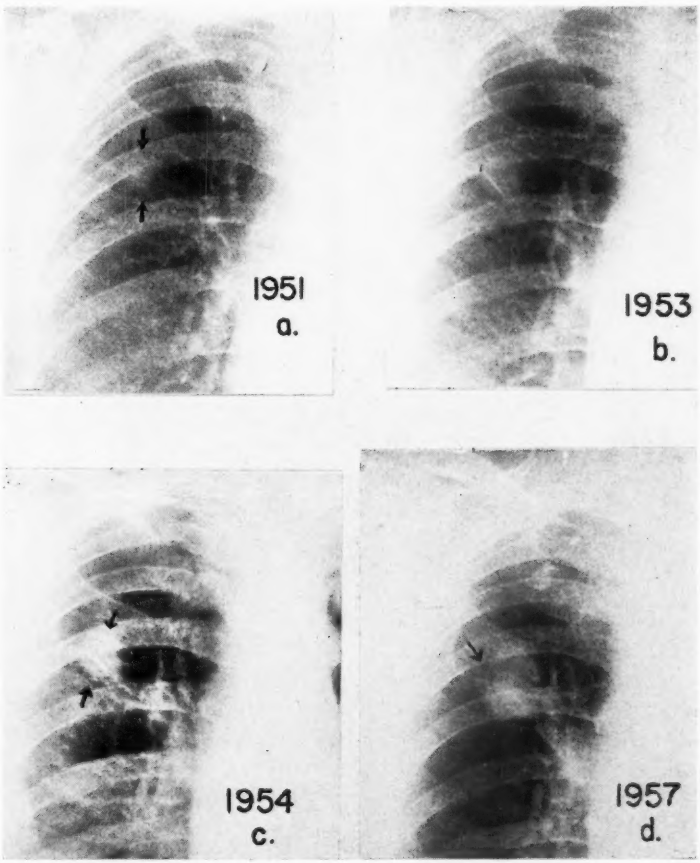

Fig. 2.—Case 2. Bronchiolar carcinoma right upper lobe.

a, Segment of roentgenogram made in 1951, presymptomatic. Note irregular area of density, peripheral nodule (arrows).

b, Same area in roentgenogram made in 1953. The shadow has increased in size and seems to sit on posterior portion of major interlobar fissure. Still presymptomatic.

c, Further increase in size (arrows) 1 year later.

d, Roentgenographic appearance at time of definitive diagnosis and surgical treatment in 1957. Note further enlargement of shadow and notch (arrow) suggestive of malignancy. Even at this time symptoms were minimal.

If this case had been recorded on the basis of the patient's symptoms, his death, which followed approximately 7 months from the last roentgenogram, would have been dated as having followed some 10 months from the time when the lesion was first discovered. It should be emphasized that the beginning of

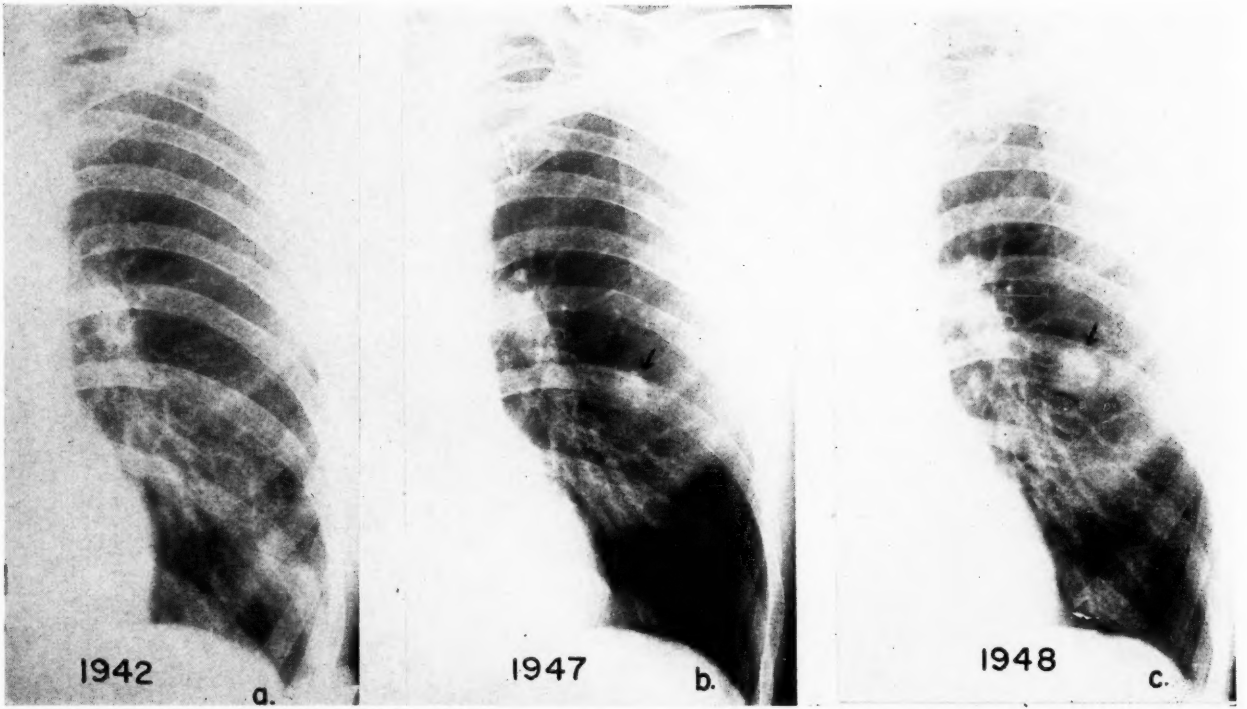

Fig. 3.—Case 3. Adenocarcinoma left lower lobe, asymptomatic throughout course.
a, Roentgenogram, left lung, 1942, apparently normal.
b, Roentgenogram, left lung, 1947, small peripheral density overlying rib (arrow).
c, Further increase in size of shadow (arrow) 1 year later.

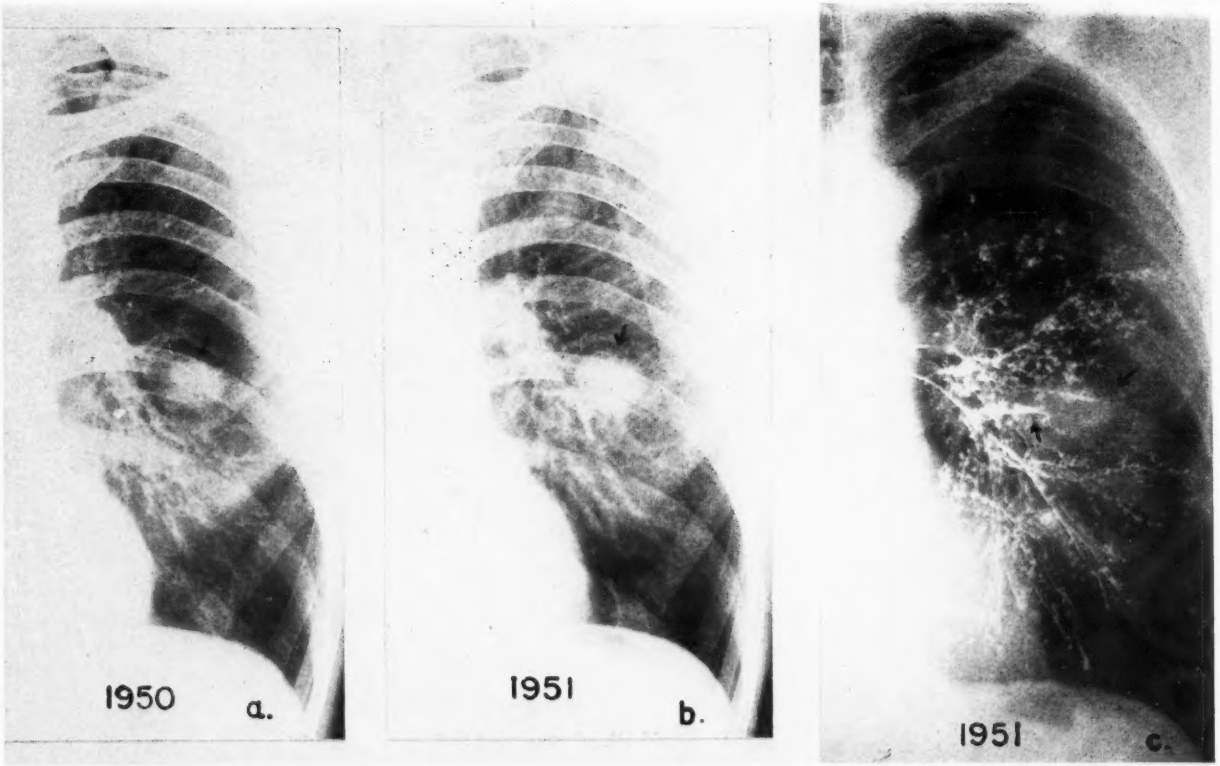

Fig. 4.—Case 3. Same as Fig. 3.

a, Roentgenogram, left lung, 18 months after film shown in Fig. 3, *c*. Further growth is seen (arrow).

b, Further increase in size 1 year later. Note that increases in size of shadow have consistently extended medially rather than laterally.

c, Bronchogram at this time when definitive diagnosis was made. The mass itself is seen (arrow) and the involved bronchus which by means of multiple views was seen to be a tertiary branch of the left lower lobe bronchus.

the symptoms was almost concomitant with the development of distant metastasis. In our experience, it is common to find such striking time differences between the first x-ray evidences of a minimal lesion and the onset of symptoms.

CASE 2.—Bronchiolar carcinoma. A woman of 60, with no pulmonary symptoms, had repeated examinations of the chest beginning in 1951. On the first film (Fig. 2, *a*), a small, irregular density is seen in the right upper lobe bordering on the interlobar fissure (arrows). In 1952, the shadow showed a minor degree of enlargement. In 1953 (Fig. 2, *b*), the shadow is somewhat larger. In 1954 (Fig. 2, *c*), the lesion is still small but now measures about 2 cm. and is distinctly larger than on the previous examination.

We saw the patient for the first time in 1957, over 6 years from the time when the first evidences of an abnormality could have been observed. The lesion was now enlarged to both sides of the fissure, was about 5 cm. in diameter (Fig. 2, *d*). On planigraphic study it showed the characteristic notching, typical of carcinoma, which can even be seen in this single film at the point of the arrow. Even at this time the symptoms were minimal and vague. At operation, this proved to be a bronchiolar carcinoma with no apparent lymph node involvement and no apparent lesions elsewhere in either lung insofar as exploration could uncover them.

Comment.—Here is a case of bronchiolar carcinoma which obviously has a history of at least 6 years' duration; how much longer it is impossible to say since the first films already shows the evidences of the process. Again, if symptoms were a criterion of the duration or the development of this process, a gross misstatement of the actual situation would have been made.

CASE 3.—Adenocarcinoma. A male veteran of 50, without pulmonary symptoms, appeared for examination in a Veterans Hospital at various occasions for a variety of minor conditions but was entirely free of pulmonary symptoms. The first record we have is a roentgenogram of the chest made in 1942 (Fig. 3, *a*) which appeared to be entirely normal. The next roentgenogram made was in 1947 (Fig. 3, *b*) in which there was seen clearly a shadow measuring about 1 cm. in size which overlay a rib and apparently was thus overlooked. Over a period of years, films were made at yearly intervals and the nodule is shown to increase in size (Fig. 3, *c*) rather gradually. In 1950, there was a further increase in size (Fig. 4, *a*). We saw him for the first time in 1951, at which time the lesion measured about 5 cm. in diameter (Fig. 4, *b*). Planigraphic studies showed the characteristic notching previously reported as indicative of carcinoma.[15] Bronchography was done and indicated that the lesion arose in a branch of the lower lobe bronchus (Fig. 4, *c*). Even at this time there were no pulmonary symptoms. At operation this proved to be an adenocarcinoma and a pneumonectomy was done.

Comment.—It is notable that throughout the period of growth the lesion has enlarged centrally. It is difficult, of course, to predict exactly what would have happened but the course of events suggests that this would have extended from the small branch bronchus into the lobar bronchus. If the patient had been allowed to go on without interruption, symptoms would then have arisen and it would have been thought that he had a lesion arising in a main branch of the left lower lobe bronchus.

BRONCHIAL OBSTRUCTION

The following cases are presented to illustrate the reconstruction of events which can be made by proper interpretation of serial roentgenograms, especially where the tumor itself can be seen and the evidences of bronchial obstruction become apparent. In the 3 cases presented here, the retrospective

investigation revealed rather large numbers of films made over a period of years. In many of these not only posteroanterior but lateral views were available, and in some even planigraphic and bronchographic studies were found. The evolution of the process as exhibited in the roentgenogram is shown in diagrammatic form on a model chest with the tracheobronchial tree superimposed. While the chest model itself is formalized for purposes of simplicity, the findings themselves have been faithfully reproduced from the roentgenograms and the position of the tumor and the changes incident to bronchial obstruction are based upon observations made of all the films made in various positions. Obviously, the exact position of the tumor cannot be determined in this fashion with complete certainty, but the probabilities that the positions as indicated in the diagrams are correct are rather large. We have followed many of these cases to surgery and to autopsy and have been able to confirm our impression as to the position of the tumor rather accurately when enough films were available and atelectasis, emphysema, abscess or an actual tumor was clearly visible in the roentgenogram.

To illustrate this procedure, the following case which has already been reported elsewhere[15a] is again reviewed.

CASE 4.—A woman was first seen by us in 1953 with symptoms of at least 4 months' duration consisting of cough, hemoptysis, pain, and loss of weight. At this time the roentgenogram of the chest presented the findings seen in the diagram (Fig. 5) dated Sept. 25, 1953. There was extensive atelectasis of the lower and middle lobes on the right side with some emphysema of the upper lobe. The left lung appeared within normal limits. In collecting previous films it was found that a film made in 1944 and in 1945 appeared normal. A roentgenogram in 1946 showed a very minimal lesion well out at the periphery of the lung. Other evidence indicates that this arose in a small branch bronchus of the middle lobe. Repeated films in 1950, 1951, and 1952 all showed this lesion in the parenchyma of the lung increasing slowly in size with the increment consistently to the medial side, indicated by careful measurements of these films. Throughout this time there were no symptoms and no evidences of bronchial obstruction. In 1952, the patient was advised to have the lesion removed, but refused, until the symptoms became apparent in 1953. As we follow the course of events (Fig. 5), it is clear that the lesion was growing centrally, first beginning to involve the middle lobe bronchus, and only when it had extended into the stem bronchus on the right side did severe symptoms appear. By this time the roentgen evidences of a bronchial obstruction were of such a degree that it was difficult to see the tumor, per se, but one could readily, on the basis of films made in several directions, localize its exact position. Planigraphic studies at this time revealed the tumor itself as a positive shadow within the right lower lobe bronchus, proximal to the middle lobe orifice, and this was confirmed by bronchoscopy and later at surgery where an adenocarcinoma was found.

Comment.—The slow and central growth of this tumor, the absence of symptoms while it was peripheral, and the onset of symptoms after it involved a major bronchus are perfectly evident. The position of the tumor and its size, as seen in the original films, make it perfectly clear that it must have arisen at some distance from its final major mass. An examination of the specimen reveals also that the extension of the tumor was well beyond its local involvement of the major bronchus. This case illustrates well the development of a major bronchial lesion from a small peripheral one and the striking difference in symptomatology as between the two.

CASE 5.—A man seen in a Tuberculosis Clinic because of an exposure to tuberculosis had a roentgenogram made for the first time in March, 1948. Retrospectively, it can be seen that there was a small density in the lower portion of the right lung, but it was not observed at that time. Six months later the shadow had increased distinctly in size, but nothing was done. Repeated examinations of this patient over a period of years show clearly, as illustrated in the diagram (Fig. 6), the central extension of this small lesion, much as in Case 4. There were no pulmonary symptoms throughout this time. Even in 1953, when the films, as shown in the diagram, exhibited clearly obstructive emphysema of the middle and lower lobes, no definite symptoms were found. It should be noted that many other roentgenograms not illustrated here were examined, all of them confirming

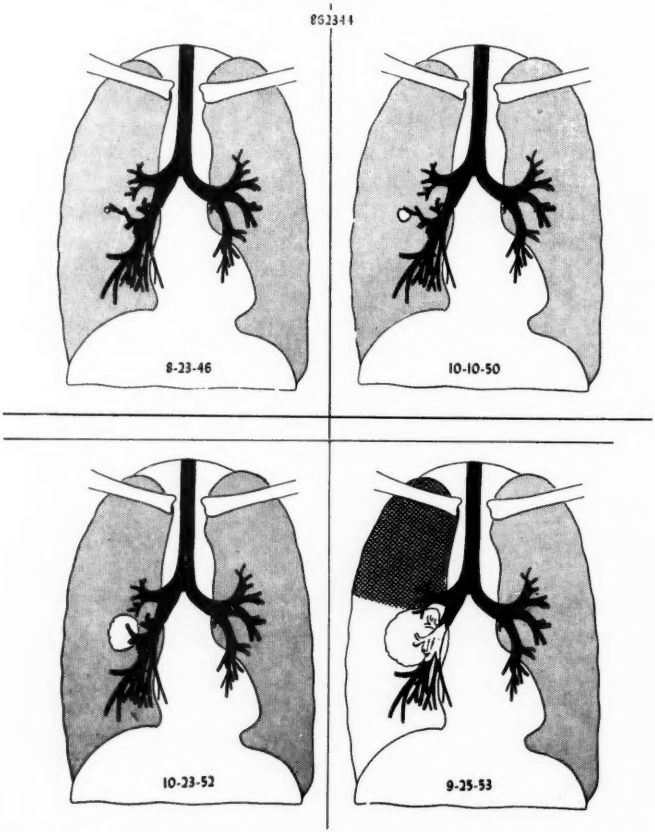

Fig. 5.—Case 4. Diagrammatic representation of evolution of peripheral carcinoma.

8-23-46. First roentgenogram showing tiny nodule right middle lobe. Film made 1 year earlier showed no shadow in this area.

10-10-50. Very moderate enlargement in 4 years. No symptoms. No signs of bronchial obstruction. Studies in following year showed further enlargement.

10-23-52. Roentgenogram shows fairly large tumor but no symptoms nor evidences of gross bronchial obstruction. Tumor is extending centrally surrounding but not obstructing branches of middle lobe. Still presymmptomatic.

9-25-53. Roentgenogram 6 months after onset of characteristic symptoms. Atelectasis and pneumonitis of right middle and lower lobes and compensatory emphysema of right upper are present. Tumor now has occluded right stem bronchus completely. Proved adenocarcinoma.

this type of growth. It can be seen from the diagram that, in 1953, the tumor had extended to obstruct partially the stem bronchus and thus produce the obstructive emphysema which is clearly apparent. It was only in 1954, when both emphysema and atelectasis were apparent, that the patient's symptoms appeared. At this time there was atelectasis of the middle lobe and obstructive emphysema of a segment of the lower lobe and atelectasis of another segment, producing a rather curious picture. Eight months later, the process having progressed, the entire stem bronchus was occluded and extensive atelectasis with "drowned" lung is clearly apparent. At this time there are shown also multiple small nodular lesions in the left lung which no doubt represented metastases. Some suppuration was present at this time, accounting in part for the expansion of the middle and lower lobes, even though they were obstructed.

Comment.—Here the final stages of the lesion occurred over 6 years after the first evidences of a tumor could have been seen in the periphery of the

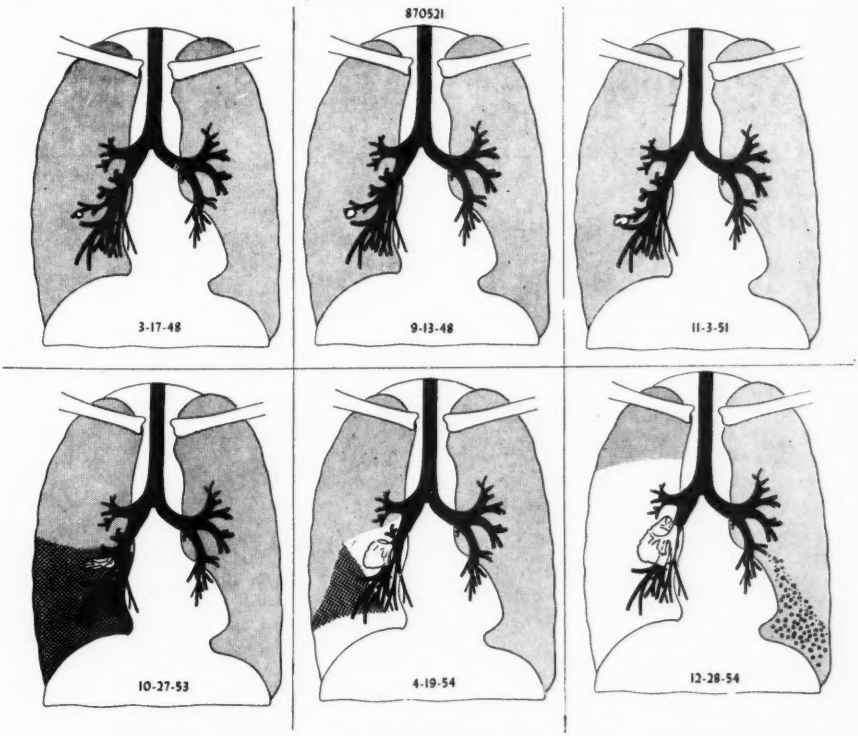

Fig. 6.—Case 5.—Diagrammatic representation of evolution of peripheral carcinoma.

3-17-48. Roentgenogram showing tiny peripheral nodule right middle.

9-13-48. Growth of tumor in 6 months.

11-3-51. Three years later shows moderate increase in size. Note medial extension.

10-27-53. Tumor has extended centrally to invade lower lobe bronchus producing partial obstruction and obstructive emphysema. There were still no symptoms.

4-19-54. Patient now symptomatic. Tumor obstructs middle lobe bronchus completely with resultant atelectasis. There is also complete obstruction of lower lobe segment but partial obstruction of remainder thus producing both atelectasis and emphysema.

12-28-54. Tumor growing centrally has completely obstructed right stem bronchus. There is now atelectasis, pneumonitis and fluid, probably suppurative, in middle and lower lobes. Metastases to left lower are now shown.

This proved to be squamous-cell carcinoma. Note 6-year course.

lung. The central extension and gradual obstruction of the stem bronchus from a small tumor arising far out are clearly seen. The transformation from emphysema to partial atelectasis and then to complete atelectasis is strikingly exhibited. This was proved to be a squamous-cell carcinoma.

CASE 6.—A 53-year-old man developed symptoms suggestive of pneumonia. He was hospitalized and apparently responded to therapy. At this time a roentgenogram of the

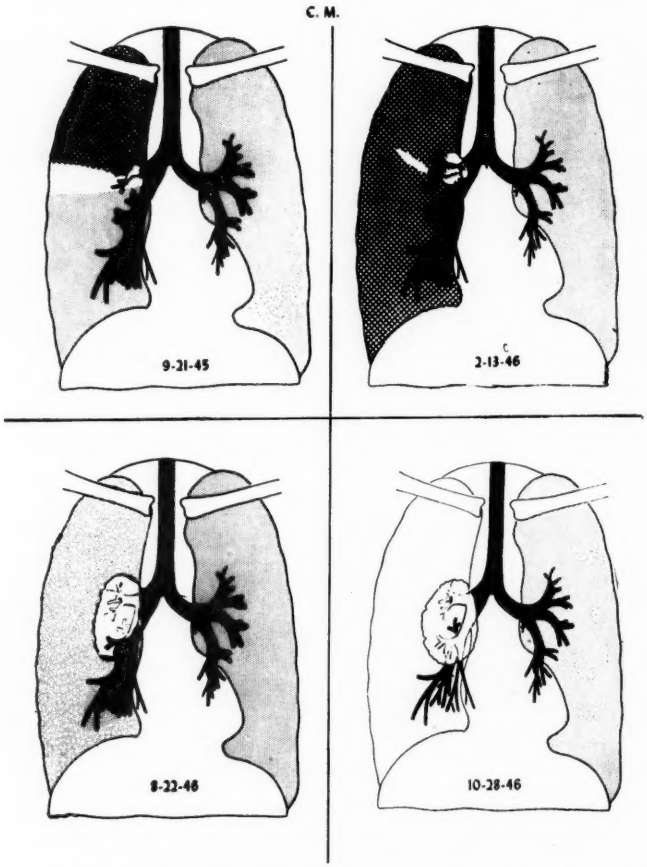

Fig. 7.—Case 6. Diagrammatic representation of evolution of bronchial carcinoma.

9-21-45. Atelectasis and pneumonitis of anterior segment of right upper lobe. Obstructive emphysema of remainder of lobe. The tumor is seen filling the segmental bronchus and by central extension partially obstructing the lobar bronchus.

2-13-46. The anterior segment has shrunken to a linear shadow and is elevated. The entire right lung shows obstructive emphysema. The tumor has grown centrally to partially obstruct the right main bronchus.

8-22-46. The entire right lung is now atelectatic with little evidence of pneumonitis. The peribronchial extension of the tumor is visible. It has extended centrally to obstruct almost completely the right main bronchus.

10-28-46. The tumor is larger and now completely obstructs the right main bronchus. The whole right lung is atelectatic with marked retention of fluid giving a high degree of opacity.

chest on Sept. 21, 1945 (Fig. 7), revealed a bandlike area of increased density in the inferior portion of the right upper lobe. Retrospectively, it is apparent that this represented a segmental area of atelectasis with pneumonitis, but at the time it was interpreted as ordinary pneumonia. In addition, it should be noted that the remainder of the right upper lobe is distinctly more radiable than the left, the appearance being quite characteristic of obstructive emphysema.

The next examination was a pre-employment photofluorogram made on Feb. 13, 1946 (Fig. 7). The bandlike shadow representing the anterior segment of the right upper lobe had now elevated itself considerably and had become a linear shadow, characteristic of the further contraction of an atelectatic segment. At this time the entire right lung was more radiable than the left, indicating further evolution of the process. In addition there was now seen a small mass in the right hilum. He was able to work for about 6 months and then developed severe symptoms of cough, dyspnea, and some loss of weight. At this time another roentgenogram (Fig. 7), dated Aug. 22, 1946, revealed a much larger mass in the right hilum. The increased radiability of the right lung was no longer apparent; in fact, there was a marked diminution in radiability. The separate atelectatic segment of the right upper lobe was not so clearly observed. Two months later the mass in the right hilum had increased considerably in size and the whole right lung had increased markedly in density. An acute process then supervened (Fig. 7, Oct. 28, 1946) and within 3 weeks the entire right lung was completely opaque, the heart displaced to the right, the diaphragm elevated, and the tumor itself no longer visible because of the extreme density of the involved lung. The patient died within a month thereafter.

Comment.—In this case, symptoms were already present at the time when the first roentgenogram was made. Furthermore, the course of events was more rapid than in the previous cases. A reconstruction of the pathologic anatomy of the tumor and its development is most interesting. As can be seen in the diagram, the tumor must have arisen in the anterior branch of the upper lobe bronchus and caused obstruction of this segmental bronchus while, at the same time, extending medially sufficiently to produce a partial obstruction of the lobar bronchus and thus the obstructive emphysema. With the passage of time the tumor extended further centrally and partially obstructed the right main bronchus while the complete obstruction of the anterior segment of the upper lobe remains. The latter contracted further, lost its fluid, thus forming the linear shadow. As the tumor grew it produced a peribronchial mass which was seen in the hilum. There was further extension into the lumen of the bronchus producing partial obstruction of the right main bronchus and with it obstructive emphysema of the entire right lung. Eventually the entire bronchus was occluded with the usual results of pneumonitis, atelectasis, and probably some suppuration. The stages through which the lung passes from emphysema, increased linear markings, and moderate diffuse density to complete opacity are well shown. The manner in which a tumor may produce atelectasis of a segment and emphysema of a lobe simultaneously is also illustrated.

DISCUSSION

There are numerous publications relating to the evolution of carcinoma of the lung which will not be reviewed here. There are, however, relatively few which approach the problem in the manner outlined above.[6, 9] The cases are reported largely to emphasize this approach.

It is evident from a consideration of these samples and from our total experience that a great many carcinomas of the lung grow slowly over a period of years before producing symptoms or signs which would lead to a definitive diagnosis. In a previous paper,[14] we calculated the average to be roughly 24 months from the first evidences seen roentgenologically until the time of operation or death, but from my experience, since the collection of that material, it would seem to me that this average is even greater.

It is clear that patients presenting with a peripheral lesion are likely to be asymptomatic until the lesion attains either a very large size within the parenchyma of the lung, or until it has grown sufficiently to invade a fairly large bronchus, or has produced symptom-causing metastases. It should be noted that we have observed some patients over a period of several years in which the lesion was central from the beginning, as exhibited by an obvious peribronchial mass, who were asymptomatic despite the presence of changes indicating partial bronchial obstruction, that is, obstructive emphysema. Nevertheless, central lesions, even in their very beginning stages, most commonly exhibit symptoms, especially if atelectasis with its attendant pneumonitis has occurred.

I have not dealt with the problem of cavitation within a peripheral mass, which in our experience is relatively common. When this occurs, symptoms will usually supervene rather rapidly.

I have not been able to collect enough cases serially studied to determine the exact percentage of those cases in which the lesion arises in the periphery and extends centrally. Certainly this must be more common than is usually considered to be the case. It is notable that Liebow,[5, 6] in his excellent discussions of the pathology of carcinoma of the lung, calls attention to the change in thinking in this regard. He, too, considers it doubtful that most of the carcinomas of the lung arise in the major bronchi. The cases which I have exhibited above indicate that if we had a good record of patients from the beginning of their process, it might well be shown that in a great many the lesion arises as an isolated tumor in the periphery of the lung and remains that way for a long period of time before the invasion of the major bronchi. The importance of this observation lies in the fact that the prognosis after surgical removal of lesions arising in the periphery is certainly better than those which are centrally placed, regardless of the histology of the lesion. This is not to say that if a lesion is peripheral it is curable. But, in general, the surgical difficulties, the invasion of contiguous structures, aside from the actual degree of malignancy of the process, make the prognosis of a lesion arising in a major bronchus far poorer, on the whole, than in the periphery. It follows then that if we could discover such lesions in the early stages of their development—not in the early stages of their symptomatology—the possibilities for surgical extirpation with good results would be greatly enhanced. This has already been indicated by the striking difference in the salvage rate of asymptomatic as

compared to symptomatic lesions of the lungs as reported by Overholt and his associates,[10-12] Davis,[4] and McBurney[7] and their colleagues, Paulson,[13] and many others.

It is important that we revise our ideas both about the origin and the rapidity of growth of carcinoma of the lung. Our own evidence indicates clearly that the majority of all cases arise in a branch bronchus rather than in a major bronchus and that in the majority of cases there is a relatively slow course of events.

SUMMARY

1. A retrospective study of roentgenograms of the lungs made fortuitously in patients with carcinoma of the lung may permit a reconstruction of the natural history of the disease in those cases in which, for various reasons, no therapeutic mechanism has been introduced.

2. A study of serial roentgenograms permits the diagrammatic reconstruction of the position of the tumor and its evolution.

3. Carcinoma of the lung grows more slowly and over a longer period of time than has generally been supposed.

4. Many cases of carcinoma of the lung arise peripherally, remain isolated and symptomless for long periods of time, but eventually grow centrally and invade a major bronchus with development of symptoms at that time.

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(For Discussion, see page 307.)

CARCINOMA-IN-SITU AND EARLY INVASIVE CARCINOMA OCCURRING IN THE TRACHEOBRONCHIAL TREES IN CASES OF BRONCHIAL CARCINOMA

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EAST ORANGE, N. J.

TWO PREVIOUS reports from our institution supported the hypothesis that when a carcinogenic agent is applied to the tracheobronchial tree, a number of changes such as hyperplasia, metaplasia, and carcinoma-in-situ usually precede the appearance of cancer. It was also found that neoplastic changes occur elsewhere in the remaining epithelium of persons who died with bronchial carcinoma.[1, 2]

The following questions arose during the course of our previous study and this paper is an attempt to answer them. (1) What is the incidence of carcinoma-in-situ in people with carcinoma of the lung? (2) What is the distribution of carcinoma-in-situ in the anatomic divisions of the tracheobronchial tree? (3) Does early invasive carcinoma occur in the remaining portions of the tracheobronchial tree? (4) Of what clinical value are these findings?

Material.—The lungs of 53 white men who were autopsied at the Veterans Administration Hospital, East Orange, N. J., were used in this study. One additional case was from the VA Hospital, Albany, N. Y., through the courtesy of Dr. Theodore Beecher. At autopsy, all these cases had frank bronchogenic carcinoma. The ages varied from 32 to 84 years and the majority of cases, 39 (72.0 per cent), were between the ages of 50 and 69 years at the time of death (Table I).

TABLE I. AGE DISTRIBUTION

AGE	NO. OF MEN
Under 40	6
40-49	4
50-59	15
60-64	14
65-69	10
70-79	3
80+	2
Total	54

From the Laboratory Service, Veterans Administration Hospital, East Orange, N. J.
Aided by a grant from the American Cancer Society.
Read at the Thirty-seventh Annual Meeting of The American Association for Thoracic Surgery at Chicago, Ill., May 4-7, 1957.

Among the 54 patients, 47 gave histories of regular cigarette smoking, 1 had smoked cigarettes only occasionally, 4 were ex-cigarette smokers, while 2 had smoked only cigars or pipes, but no cigarettes.

Methods.—Our previous reports have described a method of serially studying the histologic changes in the tracheobronchial tree. A total of 10,303 slides was made from the 54 cases studied to date. Of these, 7,993 slides with at least 10 per cent epithelium available for study were used for the basis of this analysis. Each slide was examined by three pathologists, making a total of about 25,000 examinations.

Anatomic Findings.—For the purposes of this study, the cases were divided into 2 groups according to the major involvement of the right or left lung by frank carcinoma. This was difficult in some cases because of involvement of contiguous sections of both bronchi and the trachea. In 3 cases this distinction was not possible.

Microscopic classification included 33 squamous-cell carcinomas with varying degrees of differentiation, some showing glandular features. There were 16 cases classified as undifferentiated carcinoma, 3 as alveolar cell carcinoma, and 2 as malignant cylindroma.

DEFINITION

1. *Carcinoma-in-Situ* (Figs. 1 and 2).—We have applied the same criteria for carcinoma-in-situ of the bronchus as are applied in other sites of the body, namely, (a) the basement membrane is intact, (b) there is cellular disorganization with loss of the usual layering, (c) the nuclei show a great variation in size, shape, and chromatin content, frequently with hyperchromatism, (d) there is an increase in the number of mitoses and these are often atypical, and (e) the nucleo-cytoplasmic ratio is altered in favor of the nucleus. When the tissue met all the above criteria and involved the full thickness of the mucous membrane it was designated as definite carcinoma-in-situ. When one or two of these criteria were absent or if the superficial cells were absent, leaving a scalloped surface, it was designated as borderline carcinoma-in-situ.

2. *Early Invasive Carcinoma* (Figs. 3 and 4).—We have accepted as early invasive carcinoma extension of the above changes beyond the confines of the basement membrane. We have considered it as definite when a mass of cells lies deep in the wall sometimes detached from the overlying epithelium and as border line when this distinction could not be made with certainty.

RESULTS

A. *Incidence of Carcinoma-in-Situ in the Tracheobronchial Tree* (Fig. 5).—Of the 54 cases, 48 showed some change. Definite carcinoma-in-situ was present in 735 (9.2 per cent) of the 7,993 usable slides; borderline carcinoma-in-situ, 622 (7.8 per cent) of the slides, and both definite and borderline carcinoma-in-situ in 1,357 (17.0 per cent) of the slides. The findings of either definite or borderline carcinoma-in-situ ranged from 0.5 to 59.9 per cent of the slides in any of the 48 cases.

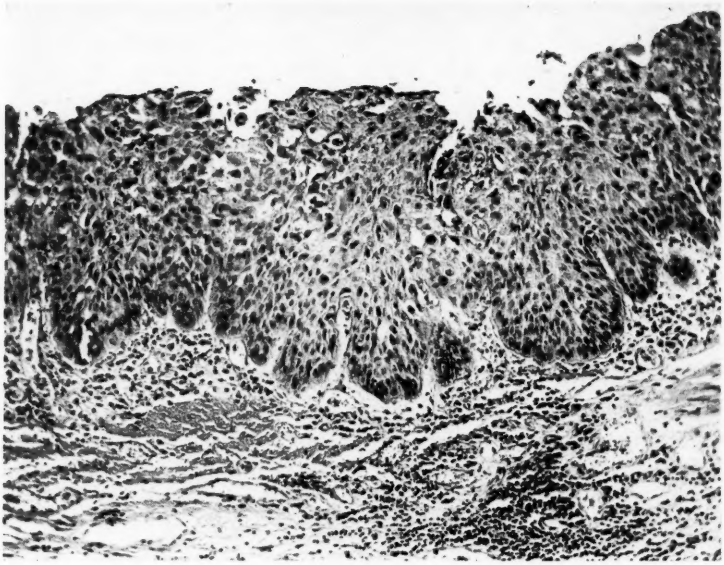

Fig. 1.—Carcinoma-in-situ (×150; reduced ⅓). The thickened epithelium shows disorientation and loss of layering of the cells. The basement membrane is intact.

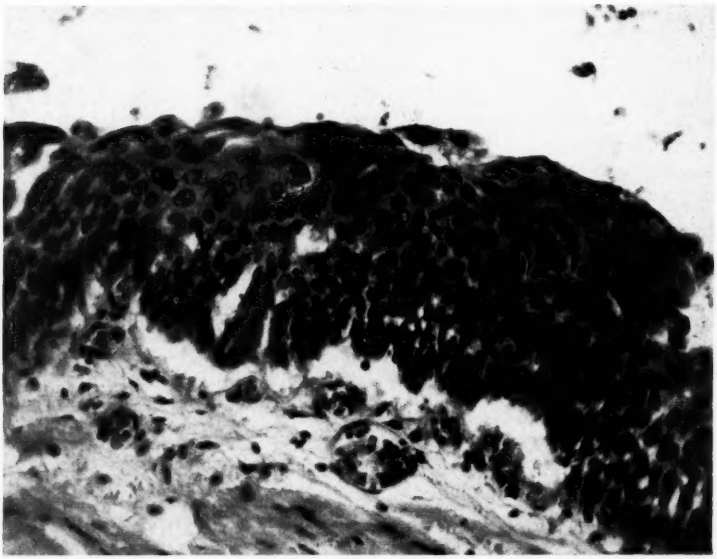

Fig. 2.—Carcinoma-in-situ (×250; reduced ⅓). The epithelium shows a cellular increase with disorganization and pleomorphism of the cells. Many of the nuclei are greatly increased in size with increased chromatin content.

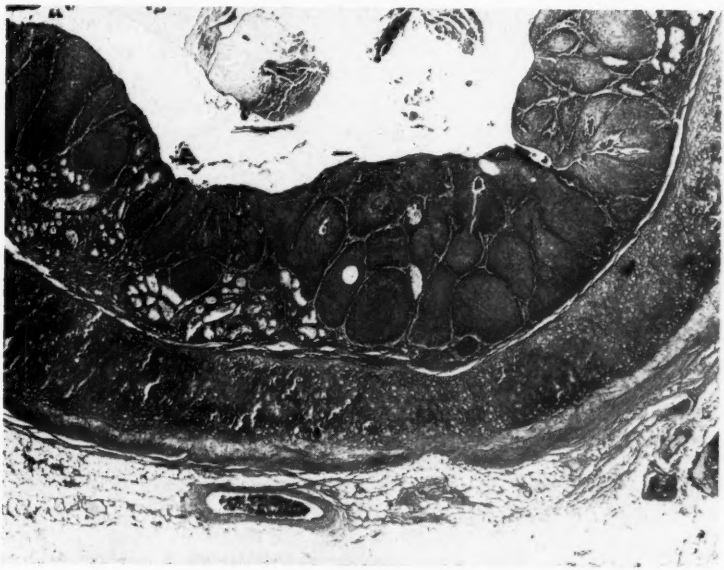

Fig. 3.—Invasive carcinoma (×7; reduced ⅓). Complete replacement of bronchial epithelium by squamous epithelial tumor cells, which have extended into the wall of the bronchus as far as the cartilage plate.

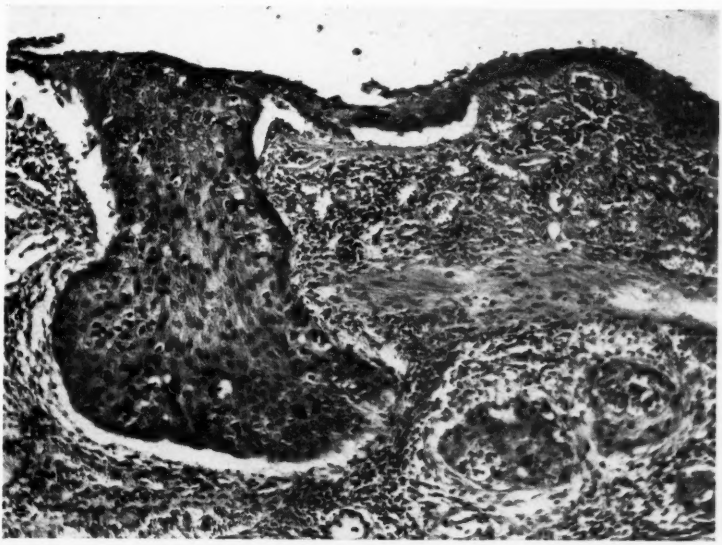

Fig. 4.—Early invasive carcinoma (×150; reduced ⅓). Squamous epithelial tumor cells in the epithelium have extended through the basement membrane into the underlying bronchial wall. Small nests of tumor cells detached from the overlying epithelium are also present.

B. *Incidence of Carcinoma-in-Situ in the Opposite Lung* (Fig. 6).—Gross carcinoma was present in the right lung in 29 cases and in the left lung in 22 cases. In 3 cases, the site of major involvement could not be ascertained with certainty and these cases have been excluded from this evaluation. Of the 51 cases, 43 showed some changes of the opposite lung. Definite carcinoma-in-situ was present in 420 (9.8 per cent) of the 4,287 usable slides from the

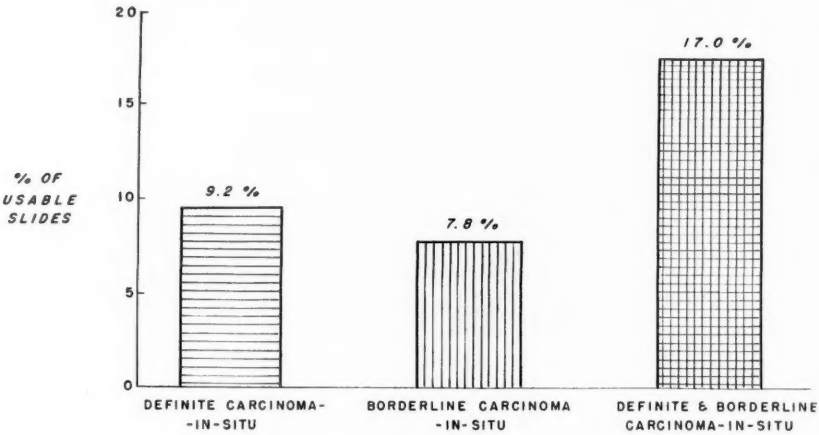

Fig. 5.—Carcinoma-in-situ in the tracheobronchial tree. (Per cent of slides with findings based on 7,993 usable slides in 54 cases.)

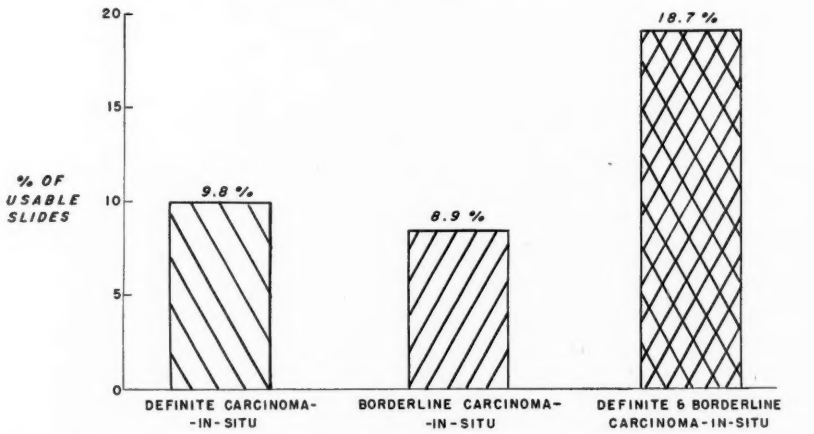

Fig. 6.—Incidence of carcinoma-in-situ in the opposite lung. (Based on 4,287 usable slides.)

opposite lung, borderline carcinoma-in-situ in 381 (8.9 per cent) slides and definite and borderline carcinoma-in-situ in 801 (18.7 per cent) slides. The finding of either definite or borderline carcinoma-in-situ ranged from 1.0 to 66.3 per cent of the slides of the 43 cases.

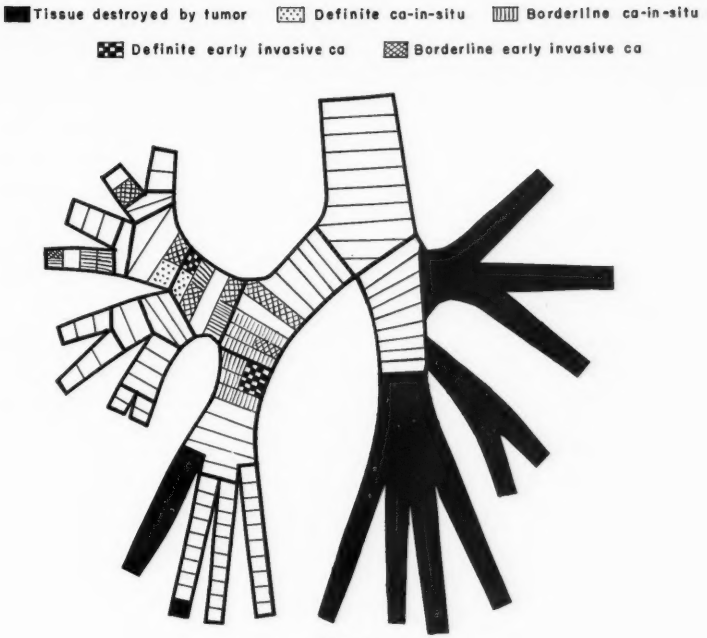

Fig. 7.

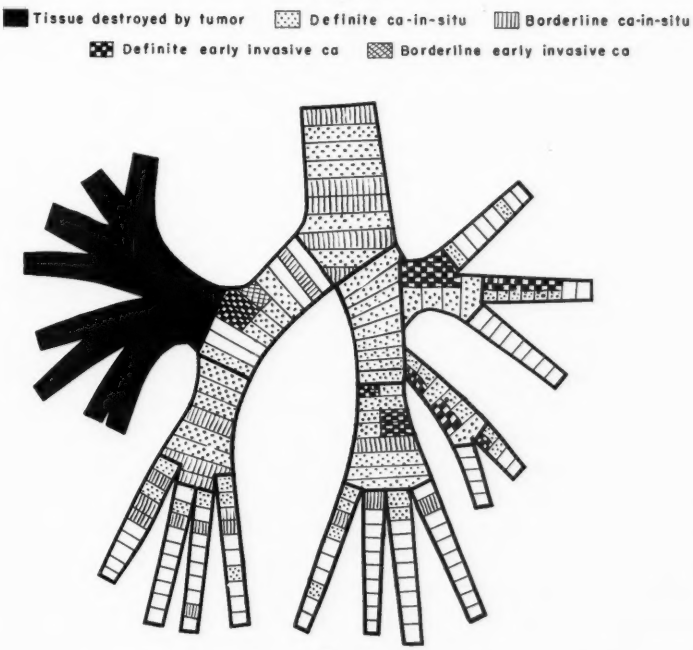

Fig. 8.

Figs. 7 and 8.—Schematic drawings of 2 cases showing the distribution of carcinoma-in-situ and early invasive carcinoma in the tracheobronchial tree.

C. *Distribution of the Carcinoma-in-Situ by Anatomic Divisions* (Table II).—In the 54 cases, no significant difference in the percentage of slides with findings could be seen in the various anatomic divisions of the tracheobronchial trees. For example, the findings of definite and borderline carcinoma-in-situ varied from 14.9 per cent of the usable slides in the trachea, 20.1 per cent of the slides in the right main bronchus to 18.0 per cent of the slides in the bronchi and bronchioles in the left upper lobe. These differences were due to sampling variations.

TABLE II

LOCATION	TOTAL NO. OF USABLE SECTIONS	TOTAL DEFINITE AND BORDERLINE CA-IN-SITU (%)
Trachea	476	14.92
Left (total)	3,681	16.93
Main	390	14.88
Upper	1,420	18.03
Lower	1,871	16.52
Right (total)	3,836	17.28
Main	354	20.06
Upper	1,047	16.91
Middle	607	15.82
Lower	1,828	17.45
Total	7,993	16.98

D. *Early Invasive Carcinoma.*—There were 5 cases with a total of 35 slides which showed either borderline or definite invasion. In 2 of the cases only one slide was involved and these were considered borderline invasion. In the remaining 3 cases, 4, 9, and 20 slides showed borderline or definite invasion. It is of interest in 2 of these cases that the foci of early invasion were present in both lungs, and of even greater interest that, in 9 instances, these changes were found in contiguous areas, a minimum of 4.0 mm. apart (Figs. 7 and 8).

DISCUSSION

A study of the tracheobronchial mucosa of a large number of individuals who died with carcinoma of the bronchus afforded us a good opportunity to observe and record alterations of the bronchial mucosa.

From the data presented, it can be seen that the over-all incidence of definite and borderline carcinoma in these cases was 17.0 per cent of the usable slides. This is a greater incidence of carcinoma-in-situ than had heretofore been reported.

Of interest is the fact that 48 of the 54 cases studied showed evidence of carcinoma-in-situ. This study included the 34 cases previously reported, 28 of which showed carcinoma-in-situ.[2] Twenty additional cases not previously reported demonstrated this lesion. We believe that this is in large measure due to improved techniques resulting in better preservation of the epithelium and greater opportunity to find the intraepithelial carcinoma.

It can be seen further that the distribution of these foci of carcinoma-in-situ, although patchy, is quite similar throughout the trachea as well as the

bronchial mucosa of the tumor-involved and the opposite lung. In some of our cases, as many as 100 slides showed these changes. Early invasion of this carcinoma-in-situ was observed in 5 of the 54 cases, apart from the clinically significant bronchogenic carcinoma.

In addition to these findings was the previously reported presence of atypical basal cell hyperplasia.[2]

The question arises as to the clinical significance of carcinoma-in-situ. We concur with the statement of Black and Ackerman[3] that carcinoma-in-situ of the uterine cervix has been linked with invasive carcinoma. Other investigators have followed the development of epidermoid carcinoma of the cervix from a study of serial biopsies over a period of several years.[4-6] They found hyperactivity of the basal cells, followed by carcinoma-in-situ, and finally invasive carcinoma. Comparable changes in the larynx have been described by Altman, Ginsberg, and Stout,[7] Miller and Fisher,[8] and by Stout.[9] It is our opinion that the same events take place in the bronchus and that carcinoma-in-situ is the pre-invasive stage of carcinoma of the bronchus. We feel that it occurs in multiple sites, and that the ultimate fate of all of these foci is a question which will require much study. However, there is evidence from this data that some of them continue on to frank invasive carcinoma.

The finding of multicentric carcinoma of the bronchus is not new. It has previously been reported both in the presence and absence of frank bronchogenic carcinoma.[10-25]

Our findings point to the view that when carcinoma of the bronchus arises from carcinoma-in-situ, it may do so from multiple contiguous foci. This is strongly suggested by our findings in 3 cases of multiple sites of invasive carcinoma apart from the overt carcinoma of the bronchus in contiguous areas. Since these individual foci of invasive carcinoma, discovered microscopically, were present in serial sections 4.0 mm. apart, it is fair to assume that if further development had been allowed, a single neoplasm would have developed from these multiple areas. It is of interest to note that McGrath, Gall, and Kessler,[20] by approaching the problem from the point of view of intraneoplastic pleomorphism, arrived at the same conclusion and felt that the lack of uniformity of the microscopic picture of an overt bronchogenic carcinoma may be due to coalescence of multiple tumors.

The clinical significance of these findings resolves itself essentially around the reasons for the low cure rate after pulmonary resection for bronchial carcinoma. Our studies suggest that so-called recurrences and metastases in some cases may be foci of carcinoma-in-situ developing in other areas which have progressed to the stage of carcinoma.

Unfortunately, although these lesions occasionally have a typical gross appearance with loss of the mucosal pattern, we have been unable in most instances to recognize them in this fashion and microscopic diagnosis has been essential.

Finally, one would like to have an answer for the infrequent occurrence of primary tracheal carcinoma in the face of our observations that carcinoma-in-situ was observed with equal frequency in the trachea (14.92 per cent) as in the left main bronchus (14.88 per cent). Unfortunately, this study does not provide a definite solution of the problem.

SUMMARY

1. A systematic examination was made of the tracheobronchial trees of 54 white men who died with bronchogenic carcinoma.

2. The ages varied from 32 to 84 years with the majority (39 or 72.0 per cent) in the age group of 50 to 69 years at the time of death.

3. Carcinoma-in-situ occurred in 17.0 per cent of the 7,993 usable slides examined or in 48 of the 54 cases (89.0 per cent). These were divided into two groups: (1) definite carcinoma-in-situ, in which all of the accepted criteria for such a diagnosis were present with an incidence of 9.2 per cent and (2) borderline carcinoma-in-situ where one or two of these criteria were absent, with an incidence of 7.8 per cent.

4. The in-situ changes were widely but somewhat irregularly present throughout all segments of the tracheobronchial tree. There was a comparable incidence of these lesions in the opposite lung as in the lung involved by overt bronchial carcinoma.

5. Early invasive carcinoma was observed in 5 of the 54 cases and occurred in one slide in 2 cases, and in 4, 9, and 20 slides in the remaining 3 cases.

6. The presence of early invasive carcinoma in the region of carcinoma-in-situ suggests that carcinoma-in-situ is a stage prior to invasion.

7. The widespread distribution of these findings offers, in part, an explanation for the discouragingly low cure rate.

We are indebted to Dr. E. Cuyler Hammond and Mr. Lawrence Garfinkel for assistance in the study and to the Medical Illustration Department of the Veterans Administration Hospital, East Orange, N. J., for co-operation.

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DISCUSSION

(PAPERS BY RIGLER [PAGE 283], AND AUERBACH AND ASSOCIATES [PAGE 298])

DR. ROBERT R. SHAW, Dallas, Texas.—These two valuable papers by Dr. Rigler and Dr. Auerbach add a great deal to our information about the early manifestations and the pathologic etiology of bronchogenic carcinoma. I want to show one illustration of a phase of this disease interrupted by surgery that fits very well the last slide shown by Dr. Rigler.

(slide) This is the roentgenogram of a 59-year-old man who, 2 days before this x-ray was taken, was admitted to the hospital complaining of chills and fever. An alert young internist suspected that there was more than just infection involved in this case. Because of his age, the unisegmental distribution, and the fact that this man had been an excessive cigarette smoker, he called for consultation. On bronchoscopy, no lesion could be seen but cells collected by bronchoscopic aspiration were considered suggestive of malignancy. An upper lobectomy was carried out after a bronchotomy done as a preliminary procedure during surgery revealed a small neoplasm. The next slide shows a cross section of the total lesion. This lesion represents a stage beyond the lesion shown by Dr. Auerbach as a carcinoma in situ, and yet it still is an intraluminal lesion with no invasion beyond the bronchial wall. It had not had the opportunity to get into the lymphatics or into the blood stream so the probability of its metastasizing at this stage is very slight. We are all aware of the significance of pneumonitis; especially recurring pneumonitis in the same segment. If we could diagnose these lesions at a time when the first pneumonitis occurs, we would find many more patients with small localized bronchial neoplasms that can be cured by surgical excision.

DR. RICHARD H. OVERHOLT, Boston, Mass.—It is important that all doctors charged with the responsibility of the detection of early carcinoma be reminded over and over again of the tremendous variation in the x-ray appearance of these lesions. Most important of all, Dr. Rigler and Dr. Auerbach have indicated that there is now evidence that many of these tumors are very slow growing and have a long latent period. This means that annual or semiannual screening should focus attention in time. Two of Dr. Rigler's points could be emphasized by relating briefly an experience with a double lesion in the same patient.

(slide) Last year, a 68-year-old lady was referred for an opinion. She was totally asymptomatic and had been through all her adult life. This is a film of the chest made in September, 1956, which reveals bilateral apical densities. The one on the right occupied one half of the area of the field of the upper lobe. On the left, the shadow was not over 1.5 cm. in diameter.

(slide) This is a spot film taken in September, 1956, which gives one a better idea of the character of the two shadows.

(slide) There were films dating back to September, 1953. Both shadows were present then. The right was only one third its later size while the left was the same in density and area.

(slide) A right thoracotomy revealed this large adenocarcinoma. A lobectomy was done. Considerable discussion then ensued as to the need of treatment for the left lesion, the small shadow of which was known to be present for over 3 years without charge. It was argued that the odds would be heavily weighted against a double malignant lesion, especially in a nonsmoking female subject.

(slide) A left exploration was carried out 3 weeks after the right. Here is the specimen. This lesion also proved to be an adenocarcinoma. The combined postero-apical segment was removed.

This case illustrates that a long observational period with growth of the shadow may represent a cancer that is still localized and, second, that a long observational period with no enlargement of a minute shadow may be caused by a latent cancer.

DR. JULIAN JOHNSON, Philadelphia, Pa.—I am very much interested in Dr. Auerbach's interpretation of the carcinoma in situ as he sees it in several areas in the lung in patients with carcinoma of the lung. I suppose that one might reason that, inasmuch as he has found a good many carcinomas in situ in the trachea, the fact that we see so few carcinomas in the trachea itself might lead one to hope that most of these carcinomas in situ would not cause any trouble in the future. In any event, it would seem probable that when a patient has a bronchogenic carcinoma removed and dies within the first year or two after its removal, we would normally think this was due to metastasis from the primary lesion rather than multiple primaries arising from these lesions as shown. It is certainly a very interesting concept, however, and would be highly significant if it could be shown that a major number of the deaths are due to new lesions arising from the carcinoma in situ.

One of our pathologists, Dr. Fred Collier, has been interested in the microscopy of carcinoma of the lung from another viewpoint, namely, that of blood vessel invasion as seen on microscopic section in the surgical specimen. By using special stains, he has been able to determine the presence or absence of blood vessel invasion without too great effort and has compared the 5-year survival rate of patients with and without blood vessel invasion. One hundred patients undergoing resection for carcinoma of the lung more than 5 years ago were studied. Whereas only 6 per cent of those with blood vessel invasion survived 5 years, approximately 75 per cent of those without blood vessel invasion survived 5 years. I am not sure that this bit of knowledge helps us any in the treatment of the patient but it does make one wonder if the patient who has blood vessel invasion doesn't already have blood-borne metastases at the time he is operated upon so that the extensiveness of his resection would have very little to do with his chances of cure.

We, of course, don't know when blood vessel invasion occurs. It does vary a great deal. We have found it in carcinomas no more than a centimeter or two across and, on the other

hand, in an occasional patient we have found it to be absent in a very large tumor. One patient, for example, upon whom I did a lobectomy, purely in palliation, feeling that it was a hopeless situation because of the large tumor which was nearly 10 cm. across, turned out not to have blood vessel invasion and is alive and well six years later. On the other hand, some of our patients with small tumors have died very soon with widespread metastasis and these were shown to have blood vessel invasion in the specimen.

DR. OSCAR AUERBACH, East Orange, N. J. (Closing).—With reference to Dr. Overholt's suggestion that there is a long latent period between the development of carcinoma in situ and overt bronchogenic carcinoma, I would agree that there seems to be increasing evidence that these lesions lie within the mucous membrane of the tracheobronchial tree for a long period. We believe this to be a fact since we have serially sectioned individuals without carcinoma of the bronchus and have found carcinoma in situ between the ages of 28 and 41 without overt bronchogenic carcinoma. We believe that these lesions were found in their stage of quiescence.

In answer to Dr. Johnson's question on blood vessel invasion, we are always up against this very important question. If you have a carcinoma of the bronchus and you section it extensively, the chances of finding blood vessel invasion are certainly greater than if just a few sections are made. We all agree then, that when tumor cells do get into both the lymphatic and venous channels the prognosis is very grave.

In answer to the question about the diffuseness of carcinoma in situ, I wish to say that we have found instances both in cases of overt carcinoma of the bronchus and those who have not developed carcinoma of the bronchus. In some cases we have found as many as 150 slides out of a total of 208 slides showing these lesions. There are obviously many questions that must still be answered, particularly why some carcinomata in situ go on to frank carcinoma and why the majority fail to do so. The important thing to remember is that there have been a few reports in the literature which have stated that when a carcinoma in situ of the bronchus is found, one can be reasonably certain that there is overt bronchogenic carcinoma in the background. This may well be so and was found in a good number of our cases, but it must also be remembered that we have found large numbers of carcinomata in situ in cases without bronchogenic carcinoma.

BILATERAL THERAPY FOR UNILATERAL SPONTANEOUS PNEUMOTHORAX

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SAN DIEGO, CALIF.

THE opportunity both to study and to treat certain diseases is afforded more often in military establishments than it is in civilian practice. Such an opportunity presented itself to the senior author during a 2-year tour of active duty with the U. S. Navy Medical Corps. While acting as head of the Thoracic Surgical Service at the San Diego Naval Hospital, he found that one of the relatively more common conditions with which he had to deal was spontaneous pneumothorax.

During the convalescence of one of our patients, following open thoracotomy for recurrent spontaneous pneumothorax on one side, a spontaneous pneumothorax developed on the opposite side. This occurrence, coupled with the facts that bilateral pneumothorax occurs in from 10 to 15 per cent[1] of patients with spontaneous pneumothorax and that recurrences are quite common in unilateral spontaneous pneumothorax, led us to adopt an investigative policy of bilateral thoracotomy for all patients admitted with a diagnosis of spontaneous pneumothorax.

Materials and Methods.—Twenty-six consecutive patients were included in this series. Nineteen of these patients were personnel on active duty, 4 were veterans, and 3 were dependent wives. Their ages varied between 18 and 47, the majority being 25 or younger.

Preoperative Preparation.—The patients were admitted directly to the Surgical Service after roentgenograms of the chest were made. Closed drainage with active suction was instituted in all cases. Depending upon the amount of fluid present, one or two catheters were inserted, via trochar, in the second interspace anteriorly and in the seventh or eighth interspace laterally. These were then connected to a 2-bottle suction system in which negative pressure could be adjusted by the height of the water in one of the bottles, while the other acted as a trap bottle. This was a particularly effective system as it

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The opinions or assertions contained herein are the private ones of the writers, and are not to be construed as official or reflecting the view of the Navy Department or the Naval Service at large.

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allowed the surgeon to increase the negative pressure to so-called "unphysiologie" heights, in order to obtain quick expansion of the lungs or to empty residual fluid within the chest.

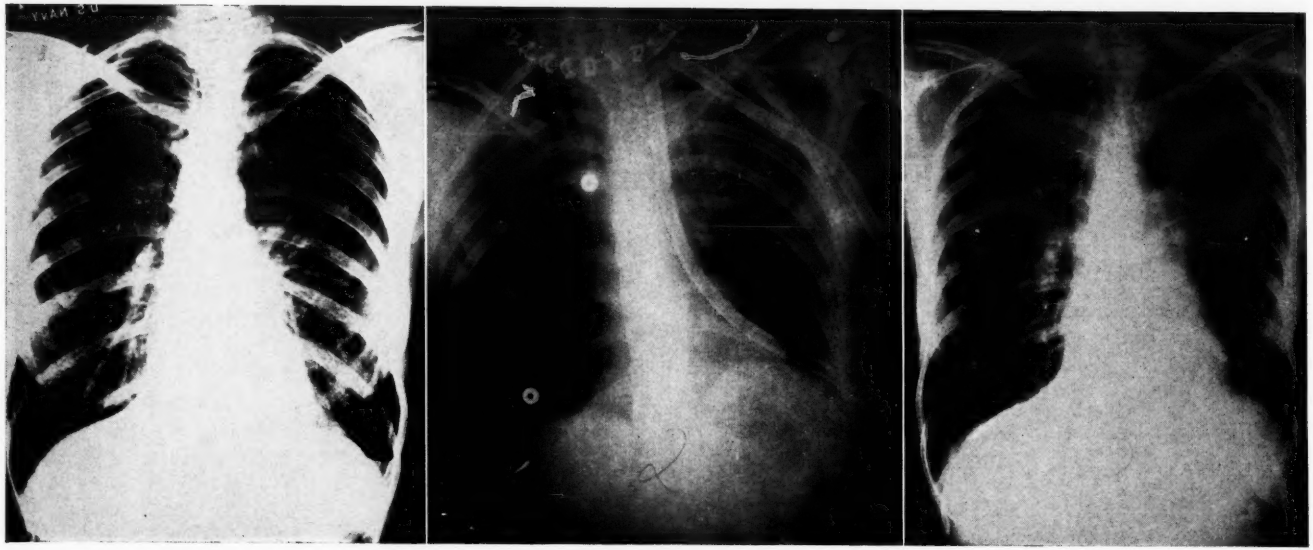
Daily roentgenograms were taken in order to ascertain the progress of the expansion of the lung. When drainage had ceased (fluid or air) for 24 hours and the roentgenogram had suggested complete expansion, the drainage tubes were removed. Antibiotics were given throughout the period of hospitalization. Surgery was undertaken after preoperative pulmonary function studies were completed, when the schedule permitted.

Operative Procedure.—A. *Thoracotomy incision:* In the very beginning of the study a staged bilateral procedure was used. This consisted of the usual right or left posterolateral incision depending upon the side on which the spontaneous pneumothorax had occurred. At a later date the opposite side was explored. The great majority of patients (24), however, were explored through bilateral thoracotomy incisions at the same sitting. Curvilinear submammary skin incisions were made bilaterally. These were not extended across the sternum. The skin incisions were extended down to the pectoralis major fascia and the breasts were reflected in that plane. The pectoralis major muscles were incised in the direction of their fibers. Upon spreading the incised muscles, the third or fourth intercostal spaces were exposed and incised. It was not necessary to open both pleural cavities simultaneously, as the definitive procedure upon the lung was carried out first on one side and then on the other side of the thorax. Exposure of the thoracic cavity after the introduction of rib spreaders without interruption of the ribs was excellent.

B. *Procedures within pleural cavities:* The surface of the lung was examined and the pathologic changes determined. Adhesions were noted and search was made for the causative factor of the spontaneous pneumothorax. Depending upon the pathologic involvement of the lungs and the stage of our study, a definitive procedure was carried out. Thus, gauze rubbing,[2] talc installation, wedge resection, segmental resection, lobectomy and parietal pleurectomy, as described by Gaensler,[1] were carried out, either singly or in combinations. After the procedure was finished, two catheters were inserted in each pleural cavity and connected to active 2-bottle suction drainage. We took particular pains in the placement of these tubes in an effort to avoid complications.

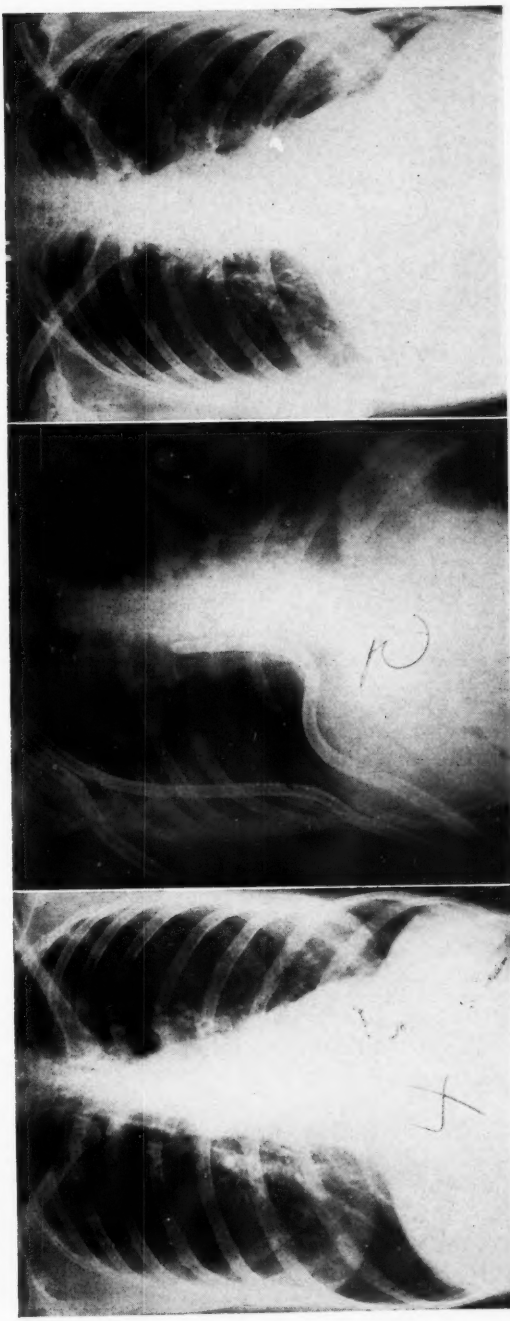
C. *Closure of chest wall:* Because of the maneuver of splitting the pectoralis major in the direction of its fibers, closure of the chest wall was not difficult. The ribs and cartilages were approximated with pericostal sutures and the muscle fibers of the pectoralis major easily approximated with either catgut or silk. The skin and subcutaneous tissues were approximated with silk and catgut, respectively. Firm pressure dressings were applied.

Postoperative Care.—Postoperative management was standardized to a high degree to facilitate nursing care, much of which was administered by highly competent and well-motivated personnel of the Hospital Corps. Blood loss was measured at surgery and replacement was given in excess of the



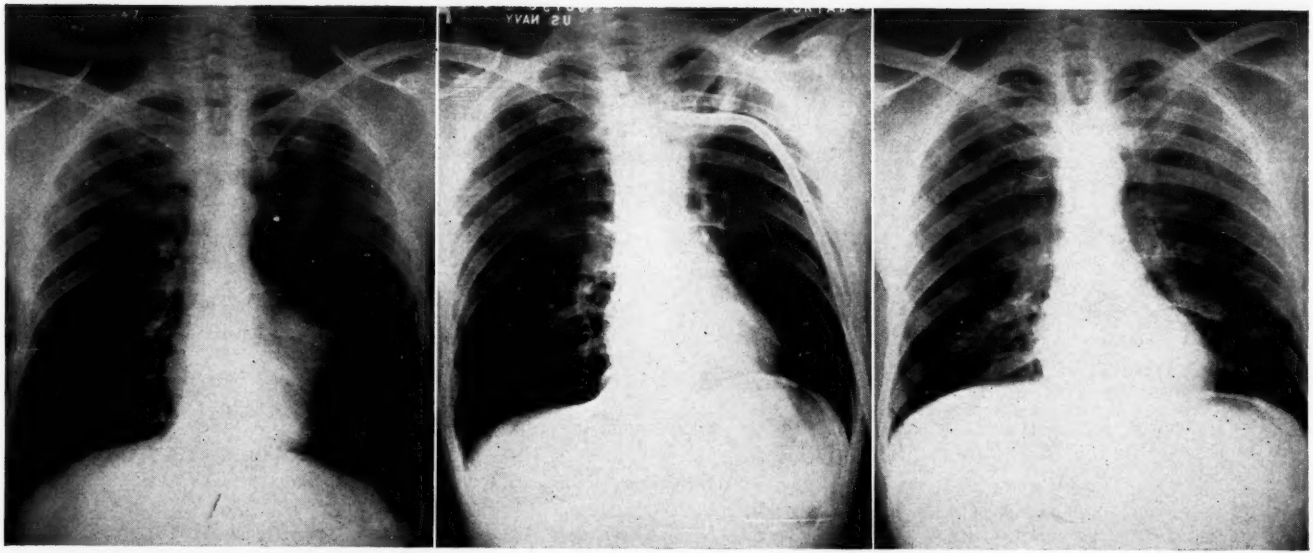
A. *B.* *C.*

Fig. 1.—Chest roentgenograms of Patient E. B. *A*, Partial pneumothorax on left 5 days before surgery. Bleb visible in right apex. *B*, Two days after segmental resection. *C*, Six months postsegmentectomy on left.



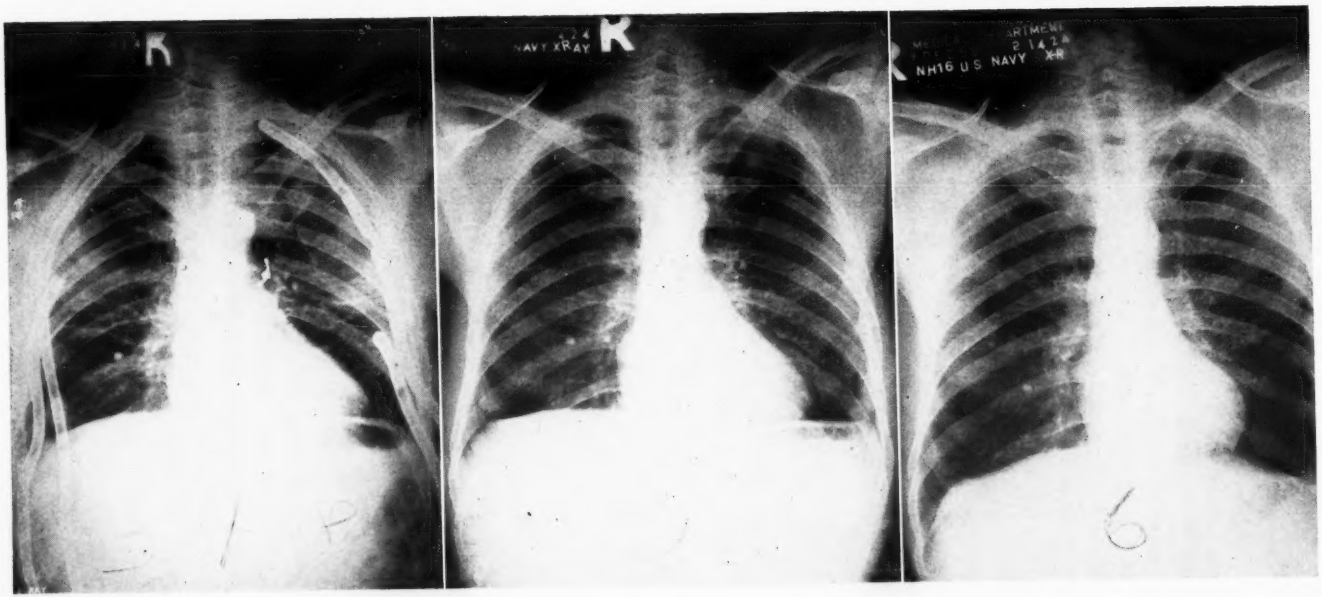
D. *E.* *F.*

Fig. 1.—Cont'd. *D*, Eleven months after. *E*, Two days after lobectomy on right. *F*, Six days postlobectomy on right.



A. *B.* *C.*

Fig. 2.—Chest roentgenograms of Patient L. H. *A*, Total pneumothorax on left. *B*, Lung expanded with intercostal drainage. *C*, Five days after drainage.



D. *E.* *F.*

Fig. 2.—Cont'd. *D*, Three days after bilateral pleurectomy. *E*, Ten days after. *F*, Seven weeks after.

measured loss. A specimen of blood was drawn on the ward for a hemoglobin determination immediately after the patient returned from surgery and was repeated daily until after the thoracotomy tubes were removed. Streptomycin and penicillin were given for 1 week and gradually decreased thereafter. The tubes were removed as soon as evidence of all drainage had ceased. All patients were out of bed the first day and completely ambulatory after the tubes were out. Breathing exercises and physiotherapy were started after one week and almost all patients were ready for duty 2 weeks after surgery. Convalescent leave, however, was given to all personnel on active duty.

Types of Surgery Performed.—In 6 patients, the intrapleural procedure consisted of rubbing the visceral pleura vigorously with a dry sponge, accompanied by wedge or segmental resection, lobectomy singly or in combinations on both sides. Bilateral resection of some sort was carried out in 9 instances. Most of these were done as a one-stage procedure.

In 4 cases, talc insufflation was carried out, 1 case having a lobectomy in addition.

In 15 patients, parietal pleurectomy (Gaensler) was carried out with or without lobectomy, wedge or segmental resection.

In one case, a segmental resection on one side and lobectomy on the other side, without ancillary procedures, were performed.

TABLE I. TYPES OF SURGERY PERFORMED

Mechanical irritation*	6
Talc insufflation	4
Parietal pleurectomy*	15
Lobectomy and segmental resection	1

*With or without lobectomy, wedge or segmental resections.

Complications.—The postoperative course was complicated with minor air leaks in 4 instances. Segmental resection had been performed in 3 of these 4 cases. In the fourth, no treatment other than tube drainage was necessary and the leaks closed promptly. In one instance, a severe bronchopleural fistula developed following an apical segmental resection. This was due to a technical error on the part of the senior author. However, the fistula was finally closed by the use of continuous suction. One hematoma and one wound infection occurred in 2 of the patients. Both of these were easily treated. A more serious complication was the occurrence of postoperative hemorrhage from an intercostal vessel that had not been ligated. This patient had to be returned to the operating room for ligation of the artery.

TABLE II. COMPLICATIONS FOLLOWING SURGERY

Minor	
Air leaks	4
Wound infection	1
Hematoma	1
Major	
Bronchopleural fistula	1
Postoperative hemorrhage	1

Findings at Surgery.—These were constant in 25 out of the 26 cases. Small, thin-walled blebs were seen throughout both lung fields. However, it was in the apices that the largest of the blebs occurred, and it was in the apices that a healed tear, suggesting this as the point of leakage, could be found in 12 instances. In many instances, the blebs were larger on the side opposite the spontaneous pneumothorax. In only 1 case was the bilaterality of the blebs not established.

Fig. 3.—Showing exposure available with bilateral simultaneous thoracotomy. Blebs are visible on patient's left (right of picture).

Thin fibrin layers over the visceral pleura were the rule and these were carefully removed. They had very little if any adhesive quality. When adhesions were present they were located at the apex of the chest and were of hair-like quality. Upon opening the plueral cavity, the lungs collapsed readily in spite of these filmlike adhesions. In 3 instances, thick adhesions were found in the apex only. This latter finding was rather surprising in a negative sense. It had been thought, before embarking on this study, that thick adhesions would be a very common finding and would obviate surgery.

Nodules were found in 5 instances associated with the apical blebs. In 4, a diagnosis of granuloma was made and in the fifth, caseation was present. This latter patient had been treated with the antituberculous drugs and this treatment was continued following surgery.

Tomography.—In an effort to discover the effectiveness of tomography in picking up contralateral blebs, this procedure was used in 15 consecutive cases. It offered little help as the films were reported negative in half the cases.

Results and Disposition.—The results in these cases proved very encouraging. Seventeen of the 19 patients were returned to full duty. Two were discharged from the service. One of these cases was an early one in the series with a lobectomy on one side and wedge resection on the other. At that time it was thought by the physical evaluation board that anyone with that type of surgery should be discharged. This feeling was corrected subsequently. The other patient was discharged for psychiatric reasons.

The 7 patients not on active duty have been leading normal lives. One of them, a woman with lobectomy on one side and segmental resection on the other, still has some shortness of breath upon moderate to heavy exertion.

Chest pain has been the most common complaint. It usually disappeared in a month, and is not incapacitating.

There has been one recurrent pneumothorax of very small degree. This occurred one month after bilateral surgery in a woman who had had only mechanical irritation of the pleura. We have since given this up.

Pulmonary Function Tests.—Each of the patients underwent pre- and postoperative pulmonary function tests. These consisted of maximum breathing capacity, vital capacity, timed vital capacity, and resting minute volume. The results obtained showed that the longer the interval following surgery the closer the postoperative study approached the preoperative. Most of the postoperative studies were performed within one month following surgery. Almost all patients were able to undertake normal activities within one month following surgery, and that included full active duty. There was some slight correlation between amount of lung removed and decrease in postoperative function; however, those that required extensive resectional surgery usually had some decrease in function, preoperatively.

DISCUSSION

In a previous review[8] of 3 years' experience at the Naval Hospital, it was found that spontaneous pneumothorax was the admitting diagnosis in one per 640 admissions. In 90 cases, the onset was accompanied by a severe knife-like pain, but only 53 patients were admitted on the same day that they experienced the pain. Thirty-nine of 114 patients were convinced in retrospect that the episode that brought them into the hospital was similar to one they had had previously. In the majority of these cases, the recurrent attacks occurred on the same side, but in 4 of the 39 cases the previous episodes had involved the contralateral side. It was suggested by this study that spontaneous pneumothorax is a serious, frequently recurrent, disease that should be treated surgically. The almost constant finding of bilateral blebs strongly suggests that therapy to both pleural cavities is in order. What type of therapy is a matter of one's own personal experience. Parietal pleurectomy as suggested by Gaensler seems to be the most logical approach yet proposed. We have gradually come around to using this maneuver and feel that it has much merit.

The one-stage bilateral approach seemed at first quite heroic, but after our first case, it was no longer deemed so heroic. It has been common experience that

the transsternal approach in cardiac surgery is well tolerated with positive pressure anesthesia.

Bilateral resectional surgery may be questioned, but our experience shows that it is also well tolerated. The major complications that did occur were directly attributable to neglect on the part of one of the operating team and completely avoidable. This should not be a criticism of the procedure but rather of the operator.

SUMMARY AND CONCLUSIONS

1. Twenty-six consecutive cases of unilateral spontaneous pneumothorax with bilateral surgery are presented.

2. Exploratory thoracotomy in one or two stages revealed bilateral blebs in 25 out of the 26 cases.

3. A variety of procedures was done to prevent recurrence: (a) mechanical irritation, (b) parietal pleurectomy, and (c) bilateral resectional surgery alone. The first two procedures were performed with or without additional resectional surgery.

4. Spontaneous pneumothorax is not a mild disease, and should be treated radically.

5. Bilateral therapy is suggested for most cases of unilateral spontaneous pneumothorax.

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DISCUSSION

DR. WILLIAM M. TUTTLE, Detroit, Mich.—I know, having met Dr. Baronofsky on several occasions, that he undoubtedly did have a wonderful time during his tour of duty in the Navy. He practically killed me on two occasions several years ago, and I do not die easily. While I like Dr. Baronofsky very well personally, I cannot go along with his theory on the treatment of the so-called emphysematous bleb with spontaneous pneumothorax. In the first place, I feel that the bilateral approach to the chest, unless it concerns some cardiac or vascular disorder, is not a good procedure and probably is extending one's hand too far. Sometimes when people are young and strong like Dr. Baronofsky they have the feeling that the patient can stand as much as they could stand. This is undoubtedly not true. Furthermore, he was operating on a group of young, strong individuals who will withstand a tremendous amount of assault. Therefore, from that standpoint it does not seem to me that this procedure is a good surgical approach to the problem. In the second place, I have

always felt than an anterior thoracic approach is an exceedingly bad one. The incision is hard to approximate and oftentimes does not heal well.

We have recently been looking up a group of our patients who have had this type of disease and upon whom we have operated. There have been only approximately 2 of 100 patients who have developed a spontaneous pneumothorax on the contralateral side after the original side had been operated upon following several episodes of spontaneous pneumothorax. It would therefore seem to me that this is just too much surgery for a disease (pulmonary emphysema) which many people have. There are probably a number of people sitting in this room who have emphysematous blebs which have never caused them trouble. Are we therefore to feel, according to this paper, that all these persons should receive surgery? I do not believe so. In numerous instances, blebs are present but cannot be seen by x-ray. That is another reason why I believe that no formal thoracotomy should be done when no definite evidence is present that they exist. I know that the older men in this room will not do this operation, but there are numerous younger surgeons who will feel that it is a much more erudite procedure than the simpler one of attempting to cure the disease which is known to be present. I feel that this warning should be passed out because, if Dr. Baronofsky's thoughts are carried in a therapeutic fashion to the type of individual seen in civilian life, much trouble will ensue.

DR. GABRIEL SELEY, New York, N. Y.—I would like to congratulate Dr. Baronofsky on an excellent presentation. He has just offered a new and somewhat aggressive treatment for a difficult problem. I would like to present briefly a bilateral recurrent pneumothorax illustrating some of the difficulties encountered when managed in a more conservative manner. This patient was a 20-year-old female.

(slide) This slide was taken in 1953 and shows an essentially normal chest.

(slide) Two years later she developed a large spontaneous pneumothorax on the left. This was treated conservatively by bed rest and having the patient lie on the affected side.

(slide) Eight days later this slide shows a partial re-expansion and this lung went on to complete re-expansion.

(slide) One year later there was a recurrence of the left spontaneous pneumothorax. This time it was treated by catheter suction and instillation of Iodochlorol, 20 c.c., by catheter.

(slide) This shows complete re-expansion of the lung and residual Lipiodol in the left lower chest cavity.

(slide) The patient then came in with a spontaneous pneumothorax on the opposite side, the right, 3 months later. This time treatment consisted of aspiration of air and instillation of 15 c.c. of Iodochlorol into the pleural cavity.

(slide) This shows both lungs completely re-expanded and residual Lipiodol present.

We have used concentrated glucose in many of these cases but recently had two infections, and therefore have switched to the use of Lipiodol and up to the present time have had no difficulty from the standpoint of infection. Time alone will prove whether open operation is more effective and more permanent than chemical pleuritis.

DR. HARVEY J. MENDELSOHN, Cleveland, Ohio.—I also want to congratulate Dr. Baronofsky and his associates on the results they have obtained, and to comment in the same vein that Dr. Tuttle did so excellently. I would not agree that either unilateral or bilateral thoracotomy is an elective procedure that should be carried out primarily in spontaneous pneumothorax. I was a little surprised at the reason, or the explanation for this in Dr. Baronofsky's cases, because in our own limited series of 60 patients with spontaneous pneumothorax, there were none who had bilateral simultaneous pneumothorax except those occurring in infants and only 2 who had an alternating bilateral pneumothorax. Only 1 of the latter required any further treatment such as bilateral thoracotomy. I took the liberty of looking into the question of the occurrence of bilateral simultaneous pneumothorax and could find only 3 cases reported in over 800 cases in the literature. It is true that about 5 per cent of patients will have an alternating bilateral pneumothorax, but this is a relatively small number.

The other thing I question is the wisdom of doing a segmentectomy for this lesion. It is a peripheral lesion and is easily wedged out, and I wondered why one would want to risk the known 10 per cent occurrence of lung leaks and more serious complications with a segmentectomy, when the lesion can be wedged out and easily closed. In our series, only 13 patients required thoracotomy and wedge resection of blebs. There were no complications in this group.

DR. IRVING M. MADOFF, Brookline, Mass.—First, I should like to ask a question and then to briefly report one case. In many cases of spontaneous pneumothorax, I have noticed that there has been an associated mild defect of the thoracic wall, such as slight pectus excavatum or slight pectus carinatum, and also a tendency to a thin anteroposterior diameter of the chest. I wonder whether Dr. Baronofsky has had occasion to note such findings in his group of patients.

In support of Dr. Baronofsky's thesis, at least in certain selected cases, I should like to present the history of one patient, a 20-year-old college student who was admitted to the hospital because of the sudden onset of dyspnea. This patient was a member of the Naval Reserve and as such had had numerous chest x-ray films at 6- to 8-month intervals starting at age 17, and these were apparently normal and were reported as such.

(slide) This is the chest x-ray film on admission. You will notice a left pneumothorax. A left closed thoracotomy was accomplished and the x-ray film taken 2 days later shows that both lungs are completely expanded. (slide)

(slide) The tube was removed and the patient was about to be discharged home when he noted dyspnea again, and the chest film shows the left lung to be collapsed once more. This time a closed thoracotomy with suction was required for a period of 10 days in order to effect complete expansion of the left lung. Once more he was about to be discharged to his home when at this point the right lung was seen to be collapsed. (slide))

(slide) A right closed thoracotomy was done. However, the right lung did not re-expand despite the fact that the tubes were changed to different positions, so an open thoracotomy was done and a large cyst, measuring 5 inches in greatest diameter, was found in the right upper lobe. The cyst was excised, a parietal pleurectomy, in the manner described by Dr. Edward Gaensler, was done and the right lung was re-expanded. The patient did very well until the ninth postoperative day, when the left lung collapsed again. (slide)

A left open thoracotomy was done, at which time I found a somewhat smaller cyst in the left apex (slide). This was excised and a parietal pleurectomy was also done. The patient has now returned to school and full activity.

The necessarily prolonged hospitalization and the sequence of events in this case suggest that, in selected cases, a more radical program may be indicated. However, I do not wish to imply a generality from this one instance.

DR. BRIAN BLADES, Washington, D. C.—Dr. Tuttle covered most of the points I wished to make in a very adequate way. There is, however, one point that has not been mentioned and that concerns pleurectomy. In my opinion, it is neither necessary nor desirable to perform pleurectomy. It complicates a simple and satisfactory operation. Bleeding after pleurectomy is not uncommon. Since the rate of recurrence without pleurectomy is very low, I think this additional hazard should be condemned.

DR. RICHARD A. RASMUSSEN, Grand Rapids, Mich.—I shall not prolong this discussion very much. I am very happy that Dr. Tuttle has preceded me and that he has covered most of the necessary details. Having myself had considerable military experience during the War, I think it might be appropriate to mention one point that has not been covered, that is, the possibility of a compensation angle developing as a result of bilateral thoracotomy. An interesting observation has been made with regard to the therapy for a benign disease. It would seem rather radical. I do not have the figures, but it would seem at this time in my own experience and that of my associates, Dr. Meade and Dr. Basinger, that we have had about 50 cases of spontaneous pneumothorax and in 3 of these there was

a bilateral occurrence. Even assuming that 10 per cent might get into difficulties with bilateral disease, and I am sure that not all of us agree about this, there might have been about 2½ patients in this group of 26 presented in the paper, who would require surgery. I am sorry I have no slides to show you, but our methods of treatment have been conservative and have usually consisted of closed drainage which is usually effective. I am sure there is no assurance even with thoracotomy, unilateral or bilateral, that there will be no recurrence of this condition. While there is little mortality, or no mortality as noted, there is some morbidity. The complication rate would seem to be about 10 per cent of the reported cases. When there is a lung removed there is danger certainly of a complication. In performing thoracotomy, bilateral thoracotomy, we only add to that risk. We are all aware of the incidence of blebs in older individuals, of the fact that they occur bilaterally, that they occur in more than one lobe, not just in the upper, and that they usually cause no difficulty. They are seen most frequently at post-mortem examination. It might be justifiable to do a bilateral operation of this type on an individual who had had a pneumothorax and who planned to go out of the country, for instance, where medical attention was not available. It seems to me that the hazard of operation in this instance is not only as great but, perhaps, greater than the hazard of the disease itself.

MR. GEORGE A. MASON, Newcastle-on-Tyne, England.—We, I am afraid, have given up silver nitrate; we have not found it consistently reliable in attempts to obtain permanent obliteration in the treatment of spontaneous pneumothorax. I myself would hesitate to subscribe to the adoption of this routine bilateral procedure described today.

MR. VERNON THOMPSON, London, England.—It seems to me that there is one indication for a bilateral operation; that is, when we have bilateral simultaneous pneumothorax. This is a very rare condition but it is, I think, a most dangerous condition and must be regarded as a surgical emergency. I personally am not in favor of chemical methods of pleurodesis because I think that they are unreliable.

DR. IVAN D. BARONOFSKY, New York, N. Y. (Closing).—I should like to thank all the discussants very much. Dr. Tuttle's remarks, of course, signal the feeling that I thought would be prevalent in this group. On his comment to the younger individuals, time will tell whether this procedure is worth while. It must be remembered that this was an experimental procedure tried on service personnel, where the situation is rather unique. I shall not try to convert anyone, but I do hope that in the future some cognizance will be given, not to the operation per se, and that latter point is very important, but to the pathology which in these instances was bilateral. Other methods of attack on this disease could be used, but it is to be remembered that the bilaterality of the disease is the important consideration that I would like to bring out.

With regard to Dr. Madoff's question, we did notice that some of the patients tended toward a pectus excavatum type, but we did not attribute any great importance to this. In regard to the question of segmental resection, it is impossible to tell preoperatively which blebs are segmental in character. When we explored the patient, if the blebs were segmental, we did a segmentectomy. If they were not, we did not. It is not a matter of sitting here and saying what to do and what not to do, but rather a matter of what is found when you get into the chest. Dr. Rasmussen said that this was a very benign condition. Unfortunately, that is not so. There are many recorded cases in which death does occur; in fact a previous study we made showed that 3 cases in a series of about 100 died of the condition. Spontaneous pneumothorax, in spite of everything, is a condition not too well investigated.

I should like to thank you for the opportunity of presenting this to you, and I do hope that the group did not get too mad at me.

THE SURGICAL TREATMENT OF CHRONIC PROGRESSIVE PULMONARY HISTOPLASMOSIS

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KANSAS CITY, MO.

HISTOPLASMOSIS was still considered a rare disease in 1945. The name, *Histoplasma capsulatum,* had been given to round or oval bodies found in the endothelial cells of certain cases of splenomegaly by Darling[1] in 1906. DeMonbreun,[2] in 1934, isolated the organism from a clinical case and proved it to be a fungus. Hodgson and associates[3] summarized 138 cases of histoplasmosis in 1950. Thirty cases of focalized pulmonary histoplasmosis were presented by Forsee and co-workers.[4] Chronic progressive histoplasmosis was described by Johnson and Batson,[5] and Bunnell and Furcolow,[6] in 1948. Sutliff and co-workers[7] and our group[8] presented cases comparable with this latter form of the disease.

In spite of all reports, and even though the clinical spectrum of histoplasmosis has greatly expanded, further knowledge of the disease is mandatory. It is well accepted that the disease may be acute, chronic, latent, or recurrent. All organs of the body may be involved. The types of illness vary from an asymptomatic group to the severe generalized fatal forms. Somewhere between these two groups, we have chronic progressive pulmonary histoplasmosis, closely resembling the re-infection type of tuberculosis, and now considered to be re-infection histoplasmosis. The present treatment of this form of histoplasmosis is similar to that of pulmonary tuberculosis before specific therapy became available.

Furcolow and Brasher[9] have presented findings which they feel are necessary to establish this form of the disease. They also stated that only 16 cases of chronic progressive cavitary histoplasmosis had been reported. Twenty-one patients with proved pulmonary histoplasmosis, all subjected to some type of surgical procedure, form the basis of this report (Table I). It is the purpose of this report to demonstrate the wide variety of pathologic pulmonary manifestations which may occur with this disease, and to illustrate how bronchogenic carcinoma, pulmonary tuberculosis, bronchiectasis, and empyema must be excluded in the differential diagnosis.

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TABLE I

NAME	AGE	ONSET	X-RAY FINDINGS	SKIN TEST		ORGANISM FOUND	HISTO. SEROLOGY		LENGTH OF OBSERVATION (MONTHS)	TREATMENT AND COURSE
				TBC	HISTOPLASMIN					
1. S. R.	58	2/15	Multiple cavities, right lung	–	+	Histo + sputum + lung	C/F test: Prec. test:	1:16 1:40	47	Right pneumonectomy; 44 mo. postop., improved and working
2. E. M.	53	7/52	Cavity and infiltration, right lung	+	+	AFB + sputum Histo + lung	C/F test: Prec. test:	Not done	55	Dual segmental resection; 43 mo. postop., improved and working
3. H. F.	41	10/53	Cavity and infiltration, RUL	–	+	Histo + sputum + lung	C/F test: Prec. test:	0 0	42	Right upper lobectomy; 39 mo., improved; coronary 1 year ago, living
4. H. H.	37	9/53	2 inspissated cavities, left lung	–	+	AFB + lung Histo + lung	C/F test: Prec. test:	1:8 0	38	Wedge resection left side; 36 mo. postop., improved and working
5. G. M.	46	12/53	Infiltration and cavity, RUL	+	–	Histo + lung	C/F test: Prec. test:	1:8 1:40	6	Right upper lobectomy; 5/13/54, dead; pulmonary embolism—10 day
6. D. B.	43	10/53	Cavity, RUL	+	+	Histo + lung	C/F test: Prec. test:	1:8 1:40	44	Right segmental resection; working
7. A. D. E.	56	12/48	Cavities, left lung; bilateral infiltration	+	+	Histo + lung + sputum	C/F test: Prec. test:	1:64 1:128	67	MRD-112 experiment; left thoracotomy; dead
8. W. E.	36	2/54	Cystic changes, L. apex, inspissated cavities, left midlung	+	+	Histo + lung	C/F test: Prec. test:	1:8 1:40	38	Left upper lobectomy; improved and working
9. R. W.	40	12/55	Bronchiectasis, LLL and lingula	–	–	Histo + lung	C/F test: Prec. test:	Not done	16	Left lower lobectomy and lingulectomy; improved and working
10. L. B.	59	3/56	6 cm. mass, right upper lobe	–	+	Histo + lung	C/F test: Prec. test:	0 0	5	Right upper lobectomy; improved and working
11. T. L. P.	49	1/55	Cavity and infiltration, LUL	–	+	Histo + lung	C/F test: Prec. test:	0 0	17	Left upper lobectomy; improved and working

12. H. T.	55	5/50	Large cavity, LUL; empyema, left	+	+	Histo + sputum	C/F test: Prec. test:	1:16 1:40	80	Left pleuropneumonectomy; died on 10th postop. day
13. M. K.	13	4/54	Coin lesion, left lung	–	+	Histo + lung	C/F test: Prec. test:	0 0	36	Wedge resection of left upper lobe; attending school
14. S. D.	18	1946	Atelectasis, right middle lobe	–	+	Histo + lung	C/F test: Prec. test:	+ +	108	Right middle lobectomy; improved and working
15. D. H.	45	8/55	Infiltration and cavitation, RUL	–	+	Histo + lung + sputum	C/F test: Prec. test:	0 0	20	Right upper lobectomy; improved and working
16. C. B.	47	4/55	Large cyst, RUL and sup. segment	+	+	Histo + sputum Histo + lung	C/F test: Prec. test:	1:16	19	Right upper lobectomy and sup. segment of RLL; improved and working
17. E. S.	50	3/54	Destroyed left lung	+	+	AFB + sputum Histo + lung	C/F test: Prec. test:	1:16	32	Left pneumonectomy; living and working
18. C. H.	55	2/56	Infiltration and cavitation, LUL	+	+	Histo + lung	C/F test: Prec. test:	0		Left upper lobectomy; living and working
19. V. K.	39	9/55	Cystic changes, right upper lung field	–	+	Histo + lung	C/F test: Prec. test:	Not done	18	Right upper lobectomy; improved and working
20. W. B.	62	8/55	Nodular mass, LUL; partial atelectasis, LLL	+	+	Histo + lung	C/F test: Prec. test:	0 0	19	Left pneumonectomy; improved and working
21. P. G.	54	8/54	Destroyed rt. lung fluid level, bronchopleural fistula	–	+	Histo + sputum	C/F test: C/F test:	1:512 1:112	24	Living, remains in hospital

MATERIAL

Tabulation of the data of the surgical cases in this report show the similarity with the cases previously reported. Three of the 21 patients had pulmonary tuberculosis in addition to pulmonary histoplasmosis. One patient had received MRD-112 for 60 days (case previously reported); 1 patient received Amphotericin B and Amebacide for 4 days, but medication was discontinued because of marked nausea and vomiting. The ages ranged from age 14 to 62. All were men except 6; there was only 1 Negro patient in the series. The duration of illness prior to surgery ranged from 1 to 74 months. The lesions were confined to the upper lung fields in 13 cases. In 4 cases, there was bilateral involvement. In 1 case, there was a destroyed lung. Twelve patients presented fibrocavitary disease, and 1 patient presented a focalized coin lesion. Two other patients presented solid lesions, but these were larger than the typical coinlike process. There was a case of middle lobe syndrome and 2 cases of bronchiectasis. Two patients had marked cystic disease. Two had had previous subtotal gastrectomy.

Eighteen patients presented upper respiratory symptoms with cough as the predominating complaint. Three patients had no symptoms, their disease being discovered on mobile x-ray survey. Seven patients had hemoptysis, varying from blood streaked sputum to marked hemoptysis. Malaise and weight loss were also frequent complaints. Excluding coin lesions, the disease has always proved to be active and progressive. Repeated roentgenograms have revealed increased disease. Table I summarizes the surgical cases. The first 7 cases have been previously published.

Seventeen of the patients returned to normal life. One had a coronary occlusion 2 years after right upper lobectomy but is alive. Three are dead. Two of these were discussed in a previous publication,[8] and are included in Table I. The third died on the tenth day following pleuropneumonectomy.

CASE REPORTS

CASE 8. W. E., a 36-year-old white waitress, was admitted to the Missouri State Sanatorium on Feb. 5, 1954. The patient stated that she had had no illness, hemoptysis, or cough. A routine public health examination had revealed several nodules in the left lung field. She was admitted to the Missouri State Sanatorium in order to rule out tuberculosis. Past history and family history were noncontributory. Physical examination revealed occasional moist râles over the left lung, posteriorly. A pectus excavatum was present. Roentgenograms showed an emphysematous left lung and cystic areas filled with material (Fig. 1). Complete blood studies were normal. Repeated sputum examinations, including culture, were reported negative for acid-fast bacilli. Tuberculin skin test was positive on second strength. Histoplasmin skin test was reported as 2+ positive. Serologic studies, on March 26, 1954, disclosed complement fixation test positive 1:8 and precipitin test positive 1:40. Bronchoscopic examination was negative. Smears for malignant cells and cultures for acid-fast organisms and fungi were negative. On Feb. 20, 1954, the patient was placed on PAS and INH, because of the possibility of pulmonary tuberculosis. On April 6, 1954, a left upper lobectomy was performed. The patient had a relatively uneventful postoperative course and was discharged on July 29, 1954. PAS and INH were continued during the immediate postoperative period. PAS stains of the resected pulmonary tissue revealed *Histoplasma capsulatum* in the macrophages. Both the complement

fixation studies and the precipitin test were reported negative, Oct. 8, 1954. The patient has been followed for 24 months and is completely asymptomatic. She has returned to her occupation as a waitress.

The above case demonstrated extensive bronchiectasis with no symptoms. Pathologic studies revealed numerous dilated saccular bronchi with the cystic areas containing a custard-like material. Distal to these obstructed areas there were subpleural emphysematous bullae. The bronchiectatic changes were similar to those found in tuberculous bronchiectasis.

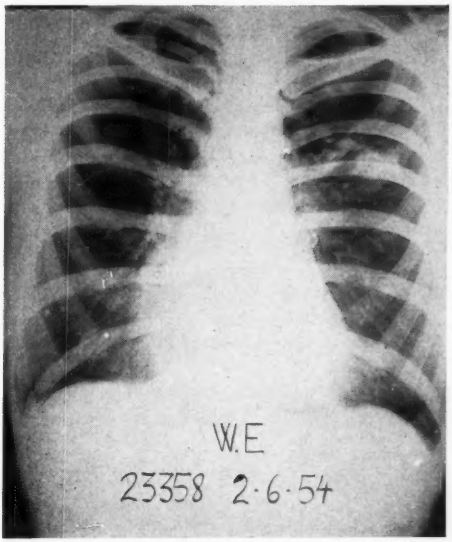


Fig 1.—Case 8 (W. E.). Roentgenograms showed cystic areas filled with material, and an emphysematous left lung.

CASE 9. R. W., a 40-year-old white woman, was admitted to the Missouri State Sanatorium Jan. 6, 1956. She stated that she had coughed up small amounts of blood in 1945 and 1949. On Dec. 14, 1955, she coughed up approximately 2 cups of bright red blood and was admitted to Burge Hospital in Springfield, Mo. After the bleeding was controlled, bronchoscopy was done on Dec. 20, 1955, followed by bronchograms. These revealed destructive bronchiectasis in the left lower lobe and lingula (Fig. 2). Left lower lobectomy and lingulectomy were advised and she was transferred to the Missouri State Sanatorium. The family and past history were noncontributory. Physical examination revealed numerous moist râles throughout the entire lower one half of the left lung. Blood pressure was 130/80 mm. Hg. Complete blood studies were within normal limits. Repeated sputum examinations were negative for acid-fast bacilli. Tuberculin skin test, first and second strengths, were negative. Histoplasmin skin test on Jan. 14, 1956 was negative. On Jan. 16, 1956, a left lower lobectomy and lingulectomy were performed. The patient had a relatively uneventful postoperative course. Tissue cultures from the operative specimen were reported positive for *Histoplasma capsulatum* on April 25, 1956. Organisms were demonstrated in the pulmonary tissue. The patient was discharged Jan. 31, 1956 and is now fully employed. She has had no further evidence of hemoptysis, or cough.

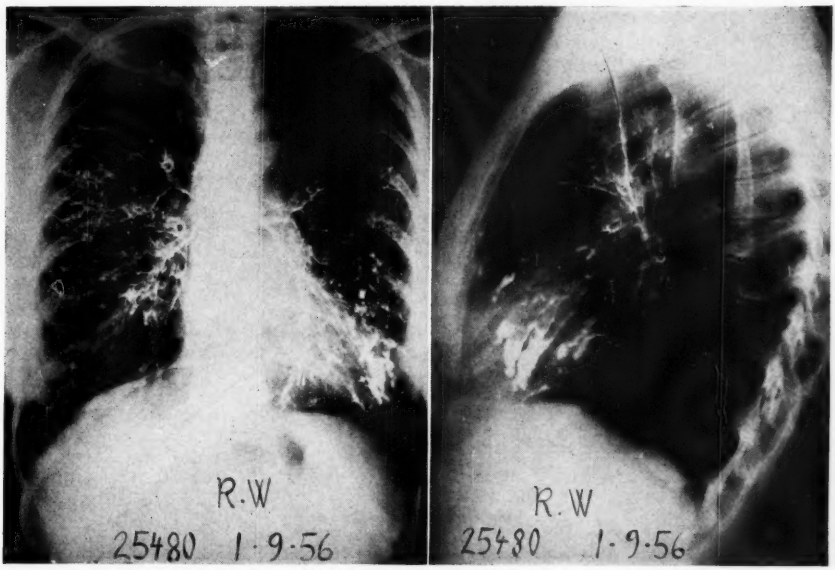
This case demonstrated active organisms in the bronchiectatic portions of the lung. Two questions arise in this type of disease: (1), did the patient contract histoplasmosis

superimposed on the bronchiectasis; (2), is the histoplasmosis responsible for the bronchiectasis? It is our opinion that this represents a true case of bronchiectasis caused by histoplasmosis.

CASE 10. L. B., a 59-year-old white man, was admitted to the Missouri State Sanatorium Dec. 12, 1956. He stated that he had had severe colds in the winters of 1955 and 1956 and had had a productive cough for approximately 5 months prior to this. During the summer of 1956, he improved and had no symptoms referable to the respiratory tract. In the fall of 1956, he again had a severe productive cough and complained of pain in the right chest. A roentgenogram revealed a dense mass in the right upper lung field (Fig. 3). Because of the possibility that this mass represented a carcinoma or a tuberculous process, he was admitted to the Missouri State Sanatorium for study. Physical examination revealed a well-nourished man who was not acutely ill, with a blood pressure of 128/70 mm. Hg. Pulmonary function studies revealed a vital capacity of 5,017 c.c. and a maximum breathing capacity of 124 L. per minute. Blood studies were normal. Repeated sputum examinations, including cultures, were negative for acid-fast bacilli. First and second strength tuberculin skin tests were negative. The histoplasmin skin test was positive. Histoplasma complement fixation studies were reported negative on Jan. 10, 1957. Bronchoscopy performed Dec. 14, 1956, was negative. Smears for malignant cells and cultures for acid-fast organisms and fungi were negative. On Dec. 20, 1956, a right upper lobectomy was performed. Frozen section studies at the time of surgery failed to reveal a malignant lesion. The patient had a relatively uneventful postoperative course. The patient was discharged Jan. 16, 1957, to resume normal occupation. PAS stains of the resected lung tissue revealed *Histoplasma capsulatum*. Cultures of the resected specimen were negative.

This large solid lesion could not be distinguished from a bronchogenic carcinoma. We believe that it represents a type of case in which resection is required for a diagnosis.

CASE 12. H. T., a 55-year-old white man, was admitted to the Missouri State Sanatorium for the second time on July 13, 1956. He had previously been a patient in this institution from January, 1950, to May 5, 1950. A diagnosis of pulmonary tuberculosis, moderately advanced, activity undetermined, was made. Chest films at this time revealed cystic changes in the apex of the left upper lobe with minimal infiltration (Fig. 4, *A*). Following his discharge, the patient remained fairly well and he resumed his occupation as a farmer until the middle of 1953 when he began to have weakness, marked dyspnea, cough, and edema of the lower extremities. He was treated by a local physician for congestive heart failure with digitalis, diuretics, low salt diet, and was advised to return to this institution but he refused. Over the next 2 years the patient's general condition greatly deteriorated. Dyspnea became more marked and after experiencing severe chest pain on the left, he was admitted to the Missouri State Sanatorium on July 13, 1956. Past history and family history were noncontributory. Physical examination revealed a chronically ill man who was extremely dyspneic and hypertensive. Breath sounds were decreased over the entire left lung. Percussion note was hyperresonant over the left. The heart was slightly enlarged and there was definite tachycardia. X-ray studies on admission (Fig. 4, *B*) revealed infiltration in the apex of the right lung. There was a large air space involving the upper two thirds of the left hemithorax and multiple fluid levels over the base. Complete blood studies revealed an anemia which was corrected with whole blood transfusions. Urinalysis was normal. Repeated sputum examinations, including cultures, were reported negative for acid-fast bacilli. Cultures from sputum were reported positive on numerous occasions for *Histoplasma capsulatum*. The histoplasmin complement fixation on Sept. 7, 1956 was reported positive 1:16, while the histoplasma complement fixation was reported positive 1:4. On July 21, 1956, an intercostal tube was inserted into the pneumothorax space and connected to an underwater sealed drainage bottle. A large bronchopleural fistula was present. Cultures from the empyema pocket were also positive for *Histoplasma capsulatum*. The empyema pocket was irrigated three times daily with



A. *B.*

Fig. 2.—Case 9 (R. W.). *A*, Bronchograms of chest. *B*, Left lung—bronchograms of chest showing bronchiectasis of left lower lobe and lingula.

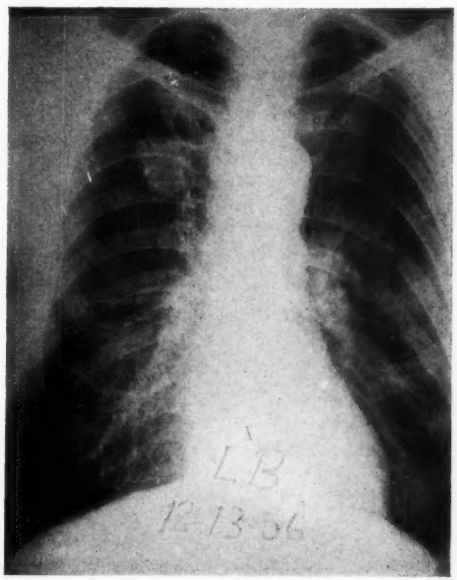
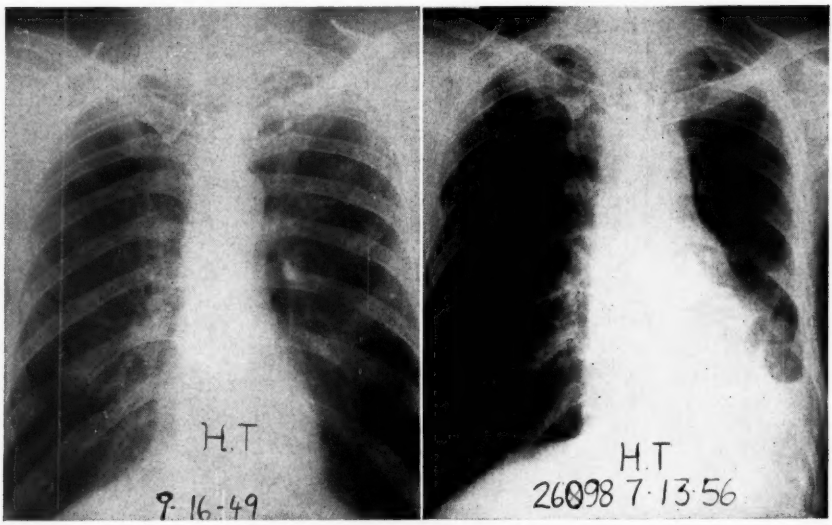


Fig. 3.—Case 10 (L. B.). Large solid lesion of right upper lung field.

Azochloramid solution. The patient was placed on Amebacide and Amphotericin B for a period of 4 days but was unable to tolerate these drugs, having marked nausea and vomiting. After 2 months on this routine, we felt the patient had reached maximum improvement and, on Sept. 19, 1956, he was taken to the operating room where we planned to close the bronchopleural fistula and do a Schede thoracoplasty. At the time of the thoracotomy, it became obvious that it was impossible to close the numerous fistulas and pleuropneumonectomy was done. The patient tolerated this surgery fairly well but in the immediate postoperative period had marked dyspnea and became psychotic. The patient died suddenly on Sept. 29, 1956. Autopsy revealed granulomatous disease in the right upper lobe in which the organism, *Histoplasma capsulatum*, was identified. A basophilic adenoma of the pituitary gland was also found along with adrenal cortical hyperplasia and chronic passive congestion of the liver.



A. *B.*

Fig. 4.—Case 12 (H. T.). *A*, (Sept. 16, 1949) shows large cystic cavity in left upper lobe.
B, (July 13, 1956) reveals infiltration and cavities in right upper lobe, empyema with multiple fluid levels, a large cavity on the left.

This case represents two features of pulmonary histoplasmosis. The first and probably the most significant is the progressive destructive nature of this disease (Fig. 4, *A* and *B*). The second is that the organism, *Histoplasma capsulatum*, may cause a definite empyema. We can find no record in the literature where the organism, *Histoplasma capsulatum*, was cultured from empyema fluid.

CASE 13. M. K., a 13-year-old white boy, was admitted to the Missouri State Sanatorium April 26, 1954. One year prior to his admission he had experienced night sweats, cough and an upper respiratory infection. These symptoms abated, but recurred in March, 1954. Roentgenogram (Fig. 5) revealed a large coin lesion in the left lung and the patient was admitted to the Missouri State Sanatorium for treatment. Past history and family history were noncontributory. Physical examination revealed a fat young male, who was not acutely ill, with a blood pressure of 126/70 mm. Hg. Complete blood studies were normal. Repeated sputum examinations, including cultures, were reported negative for acid-fast

bacilli. First and second strength tuberculin skin tests were negative. Histoplasmin skin test was positive. Serologic studies on April 30, 1954, and June 4, 1954, were negative for histoplasmin complement fixation and precipitin test. The patient was placed on INH, 300 mg. daily, and PAS, 9 Gm. daily, on June 3, 1954. On Aug. 4, 1954, a wedge resection of the nodule in the left upper lobe was performed. The patient had a relatively uneventful postoperative course and was discharged Sept. 18, 1954. He was instructed to continue on the INH and PAS for 2 months. Cultures from the resected specimen were negative for acid-fast organisms and fungi. The patient has now been followed for thirty months and continues to be in good health.

The above case illustrates a large 4 cm. nodule in a boy 13 years of age. The organism, *Histoplasma capsulatum*, was identified in the resected tissue with methenamine silver strain, whereas on previous periodic-acid Schiff stain these organisms were not demonstrated. This has been true in several cases, especially in coin or focalized lesions. We would recommend that both periodic-acid Schiff and methenamine silver stains be utilized when examining coin lesions. This case does not fulfill the criteria for diagnosis of chronic progressive pulmonary histoplasmosis, but, because of the size of the nodule, we would compare it to a large tuberculoma in a patient of the same age group.

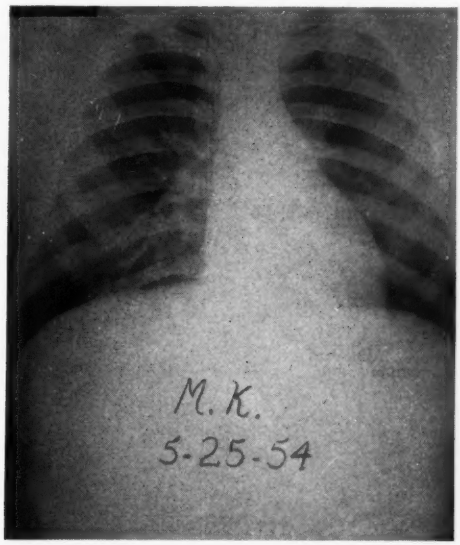


Fig. 5.—Case 13 (M. K.) Large solid lesion in left upper lobe.

CASE 14. S. D., an 18-year-old white man, had been admitted to the University of Kansas Medical Center on Jan. 1, 1952. He had been a known case of histoplasmosis since 1946, with repeated positive histoplasmin skin tests. In 1946, he had had a chronic cough with intermittent productive sputum. He coughed up bright red blood 6 weeks prior to admission. He had had a herniorrhaphy at the age of 5. A diagnosis of pulmonary histoplasmosis in the father had been made, also on the basis of a positive histoplasmin skin test. Physical examination revealed a Grade 2 systolic murmur over the base of the heart. Complete blood studies were normal. Roentgenogram of the chest revealed partial atelectasis of the right middle lobe (Fig. 6) and bronchograms which had been made in November, 1951, showed bronchiectasis in the right middle lobe. The histoplasmosis complement fixation tests were initially negative in 1946 but subsequently became positive on a number of occasions. On Jan. 3, 1952, a right middle lobectomy was performed and except

for a small postoperative pneumothorax pocket, which later disappeared, the patient had a relatively uneventful postoperative course and was discharged Jan. 17, 1952. Cultures of the resected right middle lobe failed to reveal *Histoplasma capsulatum*, but the organism was demonstrated in the tissues, using PAS stains. The patient has been followed by the United States Public Health Service, under the direction of Michael L. Furcolow, M.D., since that time. Complement fixation studies remain suggestive of histoplasmosis and his general condition remains excellent.

This case represents one of the late sequelae of histoplasmosis, that is, a destroyed middle lobe presenting as a middle lobe syndrome. The activity of disease in this type of process remains unsettled.

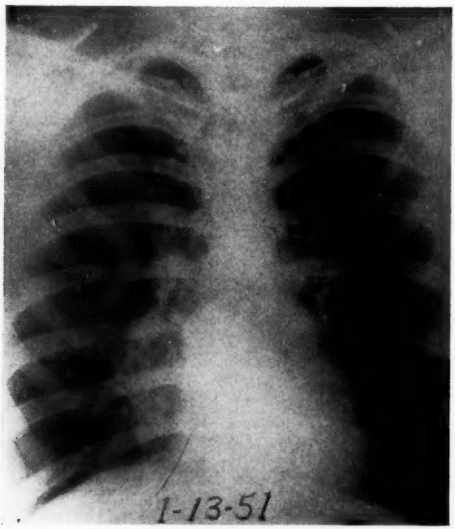


Fig. 6.—Case 14 (S. D.). Shows right middle lobe syndrome.

CASE 15. D. H., a 45-year-old white man, was admitted to the Missouri State Sanatorium Sept. 12, 1955, after having been a patient in St. Luke's Hospital, Kansas City, Mo., from Aug. 9, 1955, to Aug. 31, 1955. The patient stated that he had had weight loss, diarrhea, productive cough, and easy fatigability for 3 months prior to this. A roentgenogram revealed "spots in the right upper lung fields" (Fig. 7). He was admitted to the Missouri State Sanatorium with a diagnosis of pulmonary tuberculosis, moderately advanced, active. The past history was significant in the fact that he had had a subtotal gastrectomy performed in April, 1949. He had a previous perforated duodenal ulcer in June, 1948. Physical examination revealed two well-healed scars over the upper abdomen, and a blood pressure of 144/60 mm. Hg. Complete blood studies were normal. Repeated sputum examinations, including cultures, were reported negative for acid-fast bacilli. Tuberculin skin test was negative on both first and second strengths. Histoplasmin skin test was reported 2+ positive. Serologic studies, including the histoplasmin complement fixation test and precipitin test, were reported negative. Repeated sputum cultures were positive for the organism, *Histoplasma capsulatum*, on Oct. 15 and 18, 1955. Pulmonary function studies on Nov. 9, 1955, revealed a vital capacity of 4,700 c.c., and a maximum breathing capacity of 112 L. per minute. On Dec. 13, 1955, right upper lobectomy was performed. The patient had a relatively uneventful postoperative course and

was discharged Jan. 21, 1956. Tissue cultures from the resected lobe were reported positive on Jan. 3, 1956, and Feb. 1. 1956. The organism was also demonstrated in tissue on PAS stains. The patient has been followed for 14 months and has returned to his occupation as a farmer. A histoplasmin complement fixation test was reported positive for the first time in the postoperative period on July 27, 1956, and the organism, *Histoplasma capsulatum,* was cultured from the sputum in May, 1956. In spite of this the patient continues to show no evidence of disease on his chest films.

This case represents the most typical type of histoplasmosis for which pulmonary resection has been done, that is, chronic cavitary pulmonary histoplasmosis. In this case the largest of the cavities measured 2½ by 3 cm. This patient has also had a positive culture for *Histoplasma capsulatum* reported 6 months after right upper lobectomy. We, therefore, assume that he had active disease remaining at this time. A roentgenogram in November, 1956, shows no evidence of pulmonary involvement.

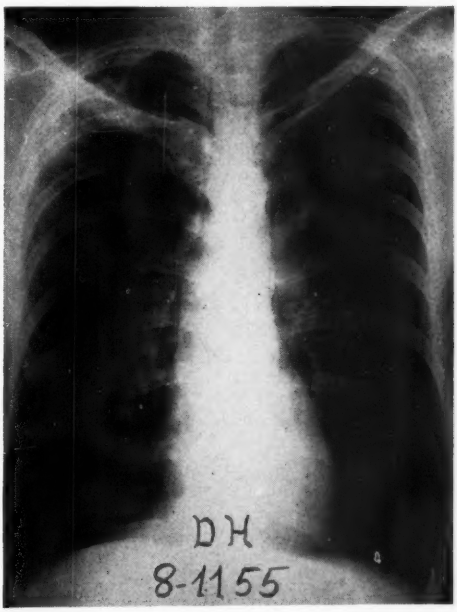


Fig 7.—Case 15 (D. H.). Infiltration and cavitation in right upper lobe.

CASE 16. C. B., a 47-year-old white man, was admitted to the Missouri State Sanatorium Sept. 28, 1955, for the second time. His previous admission had been on June 29, 1955, but he left the hospital against medical advice shortly thereafter. The patient stated that he had had cough, hemoptysis, and severe pain in the right chest since April, 1955. He had lost approximately 10 pounds in weight. A roentgenogram had been made by his local physician and, because of cavitation in the right lung (Fig. 8), he was advised to enter the Missouri State Sanatorium. On his first admission all studies were negative for acid-fast bacilli, but the organism, *Histoplasma capsulatum,* was cultured from the sputum. The patient was therefore readmitted Sept. 28, 1955, for further study. The past history and family history were noncontributory. Physical examination revealed cavernous breathing and moist râles over the posterior surface of the right chest. Blood pressure

was 130/80 mm. Hg. Complete blood studies were normal. Repeated sputum examinations, including cultures, were negative for acid-fast bacilli. The organism, *Histoplasma capsulatum*, was cultured from the sputum on several occasions. Tuberculin skin test was positive. Histoplasmin skin test was also strongly positive. Serologic studies on several occasions were reported positive on the complement fixation test in the titer of 1:16. Pulmonary function studies revealed a vital capacity of 3,500 c.c. and a maximum breathing capacity of 51.2 L. per minute. The patient had been placed on INH and PAS as a protective measure in August, 1955, and after his return to the hospital, on Oct. 3, 1955, right upper lobectomy and superior segmental resection of the right lower lobe were performed. The patient had a relatively uneventful postperative course and was discharged Oct. 31, 1955. The organism, *Histoplasma capsulatum*, was cultured from the resected lung tissue and was demonstrated in the tissue with PAS stains. The patient has now been followed for 19 months and is completely asymptomatic. He has returned to his normal occupation as a farmer.

This case shows the marked cystic changes which occur with this type of disease.

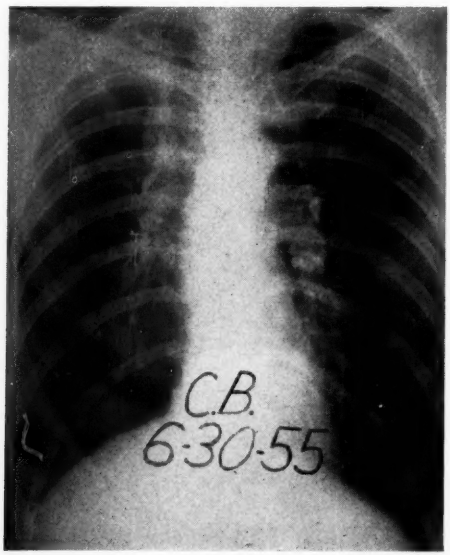


Fig. 8.—Case 16 (C. B.). X-ray studies revealed large cyst in right upper lobe.

CASE 17. E. S., a 50-year-old white man, was admitted to the Missouri State Sanatorium Aug. 26, 1954. He stated that he had had progressive dyspnea, productive cough, weakness, and poor appetite for 5 months prior to admission. He had been admitted to a hospital in St. Louis, Mo., where a diagnosis of pulmonary tuberculosis was made and he was transferred to this hospital for further treatment. Family and past history were noncontributory. Physical examination revealed a poorly nourished, white male who was acutely ill. Moist râles were heard over the entire left chest. Oral hygiene was poor. The blood pressure was 124/80 mm. Hg. Complete blood studies were normal. Repeated sputum examinations on admission were positive for acid-fast organisms. His last positive sputum examination for acid-fast bacilli was Jan. 22, 1955. The tuberculin skin test and histoplasmin skin tests were positive. Serologic studies, on Sept. 17, 1954, were reported positive 1:16 in the complement fixation test. The patient was placed on INH and PAS on

Aug. 27, 1954, and this was continued until his discharge. A pneumoperitoneum had been instituted on Sept. 30, 1954, but was abandoned after 6 months as being noneffective. Serologic studies repeated in February, 1955, were negative both in the precipitin test and complement fixation test. Pulmonary function studies, on Oct. 10, 1955, revealed a vital capacity of 2,700 c.c. and a maximum breathing capacity of 103 L. per minute. Because of the fact that the patient had a destroyed lung (Fig. 9), a left pneumonectomy was performed Jan. 18, 1956. Postresection thoracoplasty was then completed on Feb. 8, 1956. Acid-fast organisms were demonstrated in the resected lung tissue and numerous organisms identified as *Histoplasma capsulatum* were revealed by PAS stains. The complement fixation studies and precipitin tests have remained negative since surgery. The patient was discharged on June 6, 1956, and has returned to his former occupation.

This case demonstrates tuberculosis and histoplasmosis as co-existing diseases in the same patient. We have previously reported that we did not believe that tuberculosis and histoplasmosis affected each other alarmingly. This case satisfactorily demonstrates that with adequate antituberculosis therapy, pulmonary resection is warranted.

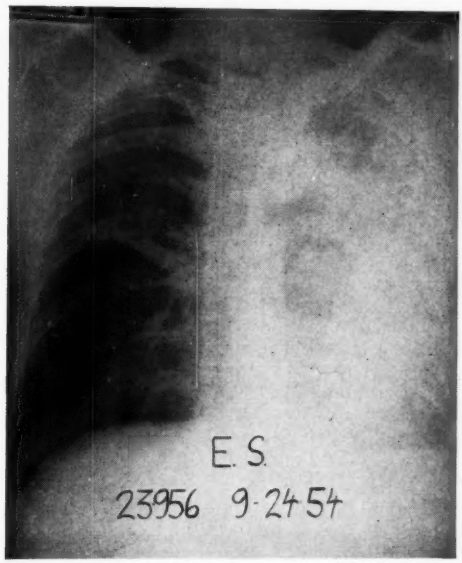
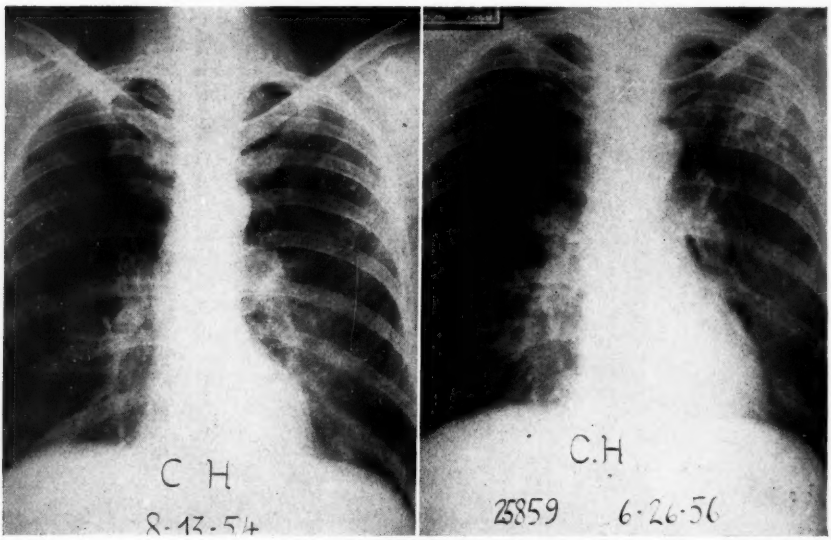


Fig. 9.—Case 17 (E. S.). Destroyed left lung (tuberculosis and histoplasmosis proved).

CASE 18. C. H., a 55-year-old white man, was admitted to the Missouri State Sanatorium May 1, 1956. He stated he had had two attacks of virus pneumonia in February and April, 1956, being treated at home by a local physician. He continued to have cough with productive sputum and lost 14 pounds of weight. A roentgenogram revealed infiltration and cavitation of the left upper lobe (Fig. 10, *B*) and the patient was advised to enter the Missouri State Sanatorium. The patient's past history was significant because of a subtotal gastrectomy which was performed in 1954 for duodenal ulcer. A roentgenogram of the chest made in 1954 had revealed only scattered calcifications in each apex (Fig. 10, *A*). Physical examination revealed occasional moist râles over the left upper lung field, posteriorly. Blood pressure was 126/70 mm. Hg. Complete blood studies were normal. Repeated sputum examinations, including numerous cultures, were negative for acid-fast bacilli. A tuberculin skin test was positive on the second strength. The histoplasmin

skin test, the complement fixation tests, and precipitin test were negative on repeated examinations. Bronchoscopic examination on June 18, 1956, was negative. Smears for malignant cells and cultures for acid-fast organisms and fungi were negative. On June 29, 1956, left upper lobectomy was performed. The patient had a relatively uneventful postoperative course and was discharged Sept. 9, 1956. The patient had been placed on INH and PAS on June 20, 1956, and this was continued until his discharge. The organism, *Histoplasma capsulatum*, was cultured from the resected lung tissue and could be easily identified in the tissues with the PAS stain. The serologic tests have remained negative since surgery.

The above case again demonstrates the progressive nature of chronic progressive pulmonary histoplasmosis as did Case 12. Although this patient had a positive tuberculin skin test, we feel that the calcification seen in each upper lung field, in 1954, probably represents histoplasmosis and not tuberculosis and that this is a re-infection type of histoplasmosis.



A. *B.*

Fig. 10.—Case 18 (C. H.). *A*, Minimal calcification in each peripheral lung field. *B*, Infiltration and cavitation in left upper lobe.

CASE 19. V. K., a 39-year-old white man, was admitted to Burge Hospital, Springfield, Mo., on Oct. 18, 1955. He stated that in September, 1955, he developed a severe cough, pain in the right chest, and a sensation of pressure in the right chest. He also complained of malaise and exertional dyspnea. He continued to work until Oct. 15, 1955, with the above symptoms persisting. A roentgenogram (Fig. 11) revealed a large cystic lesion containing fluid in the right upper lung field, and he was admitted to Burge Hospital for study. Family history and past history were noncontributory. Physical examination revealed fine moist râles over the right upper lung field. Blood pressure was 176/70 mm. Hg. Complete blood studies were normal. Tuberculin skin test was negative. The histoplasmin skin test was positive. Several sputum examinations were reported negative for acid-fast organisms. Bronchoscopy was performed and a stenosis of the right upper lobe bronchus was observed. Smears from this area were negative for malignant cells. On

Oct. 20, 1955, a right upper lobectomy was performed. The patient had a relatively uneventful postoperative course and was discharged to his home on Oct. 27, 1955. Sections of the upper lobe showed a multiloculated cyst, the largest measuring approximately 6 cm. in diameter. From this larger cyst, there were connective openings to numerous small cysts. The cyst linings were covered with a fibrinous exudate. Sections of the upper lobe bronchus showed it to be obstructed, being obliterated by fibrous tissue. Cultures of the resected specimen were not done for fungi. PAS stains revealed numerous organisms which were identified as *Histoplasma capsulatum*. The final diagnosis was benign cyst, right upper lobe, with bronchial stenosis. The patient has now been followed for 18 months and is completely asymptomatic. Serologic studies remain negative. Histoplasmin skin test remains positive. The patient has returned to his normal occupation as a truck driver.

This case demonstrates the marked cystic changes and bronchial stenosis which may occur with this disease. This is the only one of the cases in which we have been able to demonstrate a true bronchial stenosis.

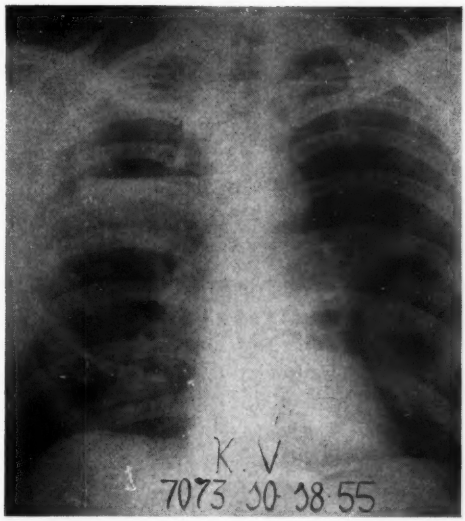


Fig. 11.—Case 19 (K. V.). Large cyst filled with fluid in right upper lobe and bronchial stenosis.

Case 21. P. G., a 54-year-old white man, was admitted to the Missouri State Sanatorium Jan. 25, 1957. He stated he had been in good health until June, 1954, when he had severe pain in the right chest, shortness of breath, hemoptysis, and productive cough. A thoracentesis on the right yielded pus which was not tuberculous. During the next few months he continued to rest at his home. Suspected as having pulmonary tuberculosis, he was transferred to this institution. His past history was significant in the fact that, in 1927, he had had a severe chest cold with hemoptysis. He stated that an abscess was drained from the right pleural space and he had had a tube in the right chest for 27 months before it healed by itself. A roentgenogram of the chest revealed a homogenous density over the entire right lung field. The heart, trachea, and mediastinum were deviated to the right. There was marked narrowing of the interspaces through the upper half of the right chest. A 7 cm. fluid level was seen over the right base. The left lung showed no pathologic changes. Physical examination revealed a chronically ill white male who showed signs of malnutrition. There was a well-healed fistulous tract and scar over the

right chest. Breath sounds were almost completely absent over the right lung. The entire area was dull to percussion. The left lung and heart were within normal limits. Marked hoarseness and paralysis of the right vocal cord were noted. The blood pressure was 135/95 mm. Hg. Complete blood studies were within normal limits. First strength and intermediate strength tuberculin skin tests were negative. Histoplasmin skin test was strongly positive. The histoplasmin and complement fixation studies were reported as positive: 1:512 and 1:128. Repeated sputum examinations, including cultures, were reported negative for acid-fast bacilli. Three sputum cultures were reported positive for *Histoplasma capsulatum*. Bronchoscopic examination, on Feb. 18, 1957, revealed paralysis of the right vocal cord with fixation of the right side of the trachea. The right primary bronchus was fixed and pushed anteriorly. The right lower lobe bronchus was almost completely closed with inflammatory tissue which was biopsied. A scalene node biopsy, on Feb. 19, 1957, showed only lymphoid hyperplasia. Pleural fluid aspirated on Feb. 7, 1957, was reported as showing cells highly suggestive for anaplastic malignancy. Numerous thoracenteses of the empyema space were done, irrigating the wound with Azochloramid and saline. A thoracotomy tube has now been placed into this space for drainage and on this routine the patient has begun to gain weight and improve clinically. It is our plan to place this patient on Amphotericin B until clinically improved.

The above case again demonstrates the destructive process of histoplasmosis. Although examination of the pleural fluid on one occasion was reported as suggestive for malignant cells, we have been unable to verify a diagnosis of bronchogenic carcinoma. Even though a bronchogenic carcinoma were present, we do not feel that the patient's present clinical condition would warrant radical pleuropneumonectomy. This is the second patient we have seen with a definite bronchopleural fistula.

Pathology of Resected Specimens and Autopsy Specimens.—Twenty-two cases of histoplasmosis have been reviewed by Puckett.[10] Four well-defined groups were found, varying from localized pneumonitis to a cavity with satellite tubercles. A survey of the pathologic findings in our series revealed only 2 cases in which the lesion resembled an isolated nodule similar to a tuberculoma. One of these has previously been reported. The other consisted of a firm 3 cm. nodule demonstrated with methenamine silver stain. Out of 37 focalized coin lesions, 21 proved cases of histoplasmosis have been demonstrated at the Missouri State Sanatorium with the use of methenamine silver stain. These are being included in another report.[11] In the 21 cases presented, 12 of the patients presented cavities of varying sizes, from 2 cm. to complete destruction of the left upper lobe by cavitation. One of the most pronounced findings was the small outcropping of cavities from the central or larger cavity. An intense inflammatory reaction was again noted in the pleura. An extrapleural resection was required in 12 cases. In 2 of the cases, a definite bronchiectasis was demonstrated. In the case with the middle lobe syndrome, bronchiectasis, and atelectasis were also present. Marked cystic changes, with bronchial stenosis in one case, were demonstrated in Cases 16 and 19. Two cases of empyema were also included and, in both of these, large bronchopleural fistulas were present. In only 1 case were we able to culture the organism, *Histoplasma capsulatum,* from the empyema fluid.

The greatest problem which has presented itself has been the diagnosis when positive cultures were absent. Few diseases present as many obstacles to establish an absolute diagnosis as histoplasmosis. In spite of positive skin reactions and positive complement fixations, no case has been considered

proved until the organism has been cultured from the sputum or demonstrated in the body tissues. Serologically proved cases are not included in this report.

Difficulty in diagnosis has been somewhat overcome with the valuable aid demonstrated when using periodic-acid Schiff or the methenamine silver stain. Furcolow,[12] in 1948, was of the opinion that if the organism could not be cultured from calcified lesions, they might not be viable. We consider all cavity cases as being active even though the organism cannot be cultured from the sputum or lung tissue. Further studies in the cultural characteristics of this organism are needed.

Serologic Studies.—Serologic studies were carried out in detail on all patients by the United States Public Health Service, Kansas City, Kansas, through the cooperation of Michael L. Furcolow, Medical Director. All of the resulting titers cannot be tabulated. In a previous report we have stated that cases were considered positive and active when the titer is higher than 1:4 on the complement fixation test, or 1:10 on the precipitin test. Further experiences with this disease have failed to prove this assumption and we would suggest that a case not be considered positive and active until the titer is higher than 1:16 or 1:32 on the complement fixation test. We had also previously stated that surgery should be deferred until the titer was 1:16 or less. It is now our opinion that the complement fixation studies are of little value in evaluating the patient for surgery and that if the clinical indications and the clinical status in the patient warrant surgery, then it can be done with relative safety.

Complete serologic studies have been utilized in the care and study of these patients. In 1 case (D. H.), the serologic studies were negative prior to right upper lobectomy. Since that time the patient has developed a positive serologic titer, even though active disease cannot be demonstrated in the lungs. Seven patients in this series presented negative serologic studies prior to surgery, and in 4 of these the organism was cultured from the sputum prior to surgery, and in each case the organism was cultured from the resected pulmonary tissue. One patient in whom the organism was cultured from the resected tissue had a negative histoplasmin skin test and negative serologic studies. From this small series it becomes very obvious that careful interpretation should be used in evaluating the serologic results.

DISCUSSION

Pulmonary resection as reported by our group[8] and several others[13, 14] appears to offer the most definite if not the only method for successful therapy in pulmonary histoplasmosis. The effects of medical therapy have been very disappointing in all forms of histoplasmosis and perhaps have contributed no more than is achieved by rest treatment or by the natural tendency of the disease to heal itself. New medicinals, such as Amphotericin B, continue to be used, and one may expect that adequate medical therapy will be established within the next few years.

The most definite indication for surgery is a localized lesion. Focalized coin lesions present no problem, regardless of the type of resection employed. Cavitary histoplasmosis, with or without tuberculosis, has constituted the largest number of our surgical specimens. It is our belief that lobectomy is the resection of choice, although several segmental resections have yielded excellent results. It is apparent from our case reports that we believe that a person weakened by histoplasmosis and remaining in a hospital for the tuberculous, with or without a diagnosis of tuberculosis, should receive adequate antituberculous therapy prior to and following resections.

Undiagnosed pulmonary lesions often warrant early thoracotomy, but each case must be individualized. In 1 case (L. B.), we felt that bronchogenic carcinoma had to be ruled out promptly, therefore, we did not wait for the routine sputum examinations or the serologic results. Another patient (W. B.) had been studied for months without a positive diagnosis, thus requiring thoracotomy for diagnosis.

The role of collapse therapy in histoplasmosis still remains an unsettled matter. Few surgeons have had experience enough with this little known disease to establish the indications for thoracoplasty or plombage. Thoracoplasty prior to resection may well be indicated in an attempt to stabilize the disease prior to resectional procedures.

Bronchial stenosis, bronchiectasis, cystic changes in the lung, middle lobe syndrome, and large solid undiagnosed lesions are accepted indications for surgery regardless of the etiology of the disease, if the patient's clinical condition warrants it. Because of the difficulty in proving a diagnosis of pulmonary histoplasmosis, we have frequently operated on such a basis. Our results in these undiagnosed cases suggest that resection can be employed as safely as for other pulmonary disease.

The histoplasmin skin test has been positive in the majority (19) of these cases. In 10 cases there were positive tuberculin skin tests. We believe that the intensity of the skin reaction is especially significant. It is recommended that serologic studies be made prior to the administration of the skin test. If a patient's x-ray studies show a disease process resembling tuberculosis, and if he presents a positive histoplasmin skin test, but a negative tuberculin skin test, we consider this a case of pulmonary histoplasmosis instead of tuberculosis, until proved otherwise.

SUMMARY AND CONCLUSIONS

1. Pulmonary histoplasmosis may occur as a re-infection or relapsing disease. The progressive nature of this disease is also demonstrated in these case reports.

2. Pulmonary resection appears to offer the best results in the therapy of chronic progressive pulmonary histoplasmosis. It is now widely advocated, but further experiences, along with follow-ups, will be needed before final evaluation can be ascertained.

3. Pulmonary histoplasmosis and tuberculosis occurring as co-existing diseases are not uncommon. Antituberculous therapy prior to resection is indicated.

4. Serologic studies have been performed in the majority of patients, but the benefits of the serologic studies are uncertain. The histoplasmin skin test seems to be more reliable as a diagnostic guide in attempting to prove the diagnosis of histoplasmosis.

5. A wide variety of pathologic manifestations of pulmonary histoplasmosis have been demonstrated. It is often impossible to differentiate these processes from those of pulmonary tuberculosis. We suspect pulmonary histoplasmosis in those cases in which all attempts to prove tuberculosis have failed, and in cases of tuberculosis in which we have positive histoplasmin skin tests, and in which the clinical response to antibiotics for tuberculosis is not satisfactory.

We wish to express our appreciation to the Department of Pathology, Dr. Sweany, Dr. Coller, and Dr. Gorelich; also to James Jones, H. T., of our Laboratory, for his work on the histologic portions of this paper, and to Mr. Earl York, employee of the Sanatorium, for his photographic work on the specimens.

We are indebted to Dr. Furcolow for permission to use Case 14.

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DISCUSSION

DR. JOHN M. SALYER, Denver, Colo.—I should like to congratulate Dr. Polk on his excellent presentation of this very important problem. I have some slides that have some bearing on the subject and I think it would be of interest to show them.

(slide) This is a photograph of a 25-year-old airman who was serving in Alaska in December of last year, when he developed easy fatigability, a feeling of lethargy, and no other symptoms until January of this year when he noticed swelling of the right side of his neck, face, and right shoulder girdle. This shows the swelling of the right chest as well as some on the left; the neck enlargement is evident. He was thoroughly examined in an Air Force hospital in Alaska, where they did a scalene node biopsy, which proved to be negative. At this time he began to have syncopal episodes. He was transferred to us early in March, with an x-ray picture as shown. (slide) We knew there was something obstructing the superior vena cava, and we found a generalized lymphadenopathy. A large axillary node approximately 2 cm. in diameter was biopsied, which proved to be negative. The skin tests were all negative except histoplasmin which was positive 2+, 1/1000 strength. It was felt by many of us that he probably had a lymphoma from the severity of the mediastinal obstruction. It was recommended initially that he have x-ray therapy, and then we surgeons put in our bid for a diagnostic thoracotomy and additional surgical measures that might seem indicated.

(slide) Here is what we found: a thrombotic superior vena cava, and here is the occluded azygos vein which was severed. There was no bleeding whatsoever—it was completely occluded, as was the superior vena cava at this point. We severed it at this level, there was a little bleeding from the distal side and none whatsoever from the heart side. While we were doing this we dissected through this fibrous tissue into the mediastinum and found a lymph node that was, on gross examination, a granuloma. We were fairly sure that we had a nonmalignant disease, that is, nonmalignant so far as neoplasm was concerned, although the fibrous mediastinitis seemed very ominous indeed.

(slide) We hoped to be able to use a "Y" aortic homograft to connect this up with the left and right innominate. However, the left innominate was so involved in this process that it was too thickened and fibrotic, and we therefore had to anastomose the aortic graft to the right innominate and proximally to the stump of vena cava near the right atrium.

(slide) This is the section through the center of the obstructed superior vena cava. This is the collagenous response to this process, and this is what you get when you resect only the fibrous capsule of such granulomatous lesions; thus, not diagnostic tissue. One must get a lymph node that contains the causative organisms.

(slide) This is not, as the pathologists describe it, a granuloma in the true sense of the word. You do not see any epithelioid cells, you see histiocytes and reticulocytes, plasma cells, and round cells. This is from the center of the lymph node—a rather odd type of granulomatous process.

(slide) This demonstrates the *Histoplasma capsulatum* organisms as stained by the Gomori silver methenamine method.

(slide) Here is the patient 11 days after surgery. This was done by unilateral thoracotomy approach. Here you see the marked decrease in swelling of the neck and chest. It is now 2 months since the vascular graft was placed in the mediastinum. At this time he is asymptomatic and appears physically fit.

(slide) Here are the preoperative venous pressure determinations: 440 mm. on the right, 440 mm. in the left arm. Eleven days after surgery, it was 150 mm. of saline on the right and 280 on the left. Since then it has improved somewhat.

Some of the personnel at the hospital suspected histoplasmosis, as the patient had lived and served in the histoplasmosis belt, in Kansas and Missouri. There was no significant past history.

DR. JOSEPH W. PEABODY, JR., Washington, D. C.—Dr. Polk is to be commended on his splendid paper, a real contribution on a subject having tremendous implications for every thoracic surgeon. In an attempt to re-emphasize the extremely broad clinical spectrum of this disease I would like to summarize our own experience with pulmonary histoplasmosis.

We have come to learn that anything tuberculosis can do, histoplasmosis can do as well, even rivaling it in frequency. For example, we have been able to establish a clear-cut diagnosis in the instances which follow.

Types	*Cases*
Diffuse (bronchopneumonic or miliary)	11
Localized pneumonic	3
Primary complex	3
Solitary parenchymal granuloma	56
Multiple parenchymal granulomas	2
Mediastinal granuloma	7
Bilateral hilar adenopathy	2
Unilateral hilar adenopathy	4
Pleural effusion	2
Re-infection type (apical fibrocavitary)	5
Thin-walled cavity	2
Broncholithiasis	1
Middle lobe syndrome	2
Incidental finding (small parenchymal or mediastinal focus; incidental to carcinoma, etc.)	6
Total	106

Thus, we have seen 106 cases of what we would consider "benign" pulmonary histoplasmosis. By contrast we have seen only 4 instances of progressive disseminated histoplasmosis and several of these we were asked to see only after the diagnosis had been established. In other words, the healed or healing forms of the disease are the important ones. They are there, if one but looks for them.

Dr. Rigler showed so beautifully this morning the evolution of bronchial carcinoma; the evolution of certain types of histoplasmosis is equally interesting. (slide) So far as I know this is the only documented example of the radiographic evolution of an histoplasmoma. A roentgenogram taken 3 years earlier shows a larger patch of pneumonia in the identical area. This had been previously called with great assurance "virus pneumonia." Even before encountering this case, I have often wondered how often a patient with pneumonia, supposedly viral in etiology, converts his histoplasmin skin test in the course of the infection.

Be that as it may, my real reason for showing this slide is to call attention to the place where this first roentgenogram was taken, namely, Concord, Massachusetts, where there isn't supposed to be any histoplasmosis! Yet from the patient's long uninterrupted residence in that locale (without benefit of any vacation outside of that state), the disease could not have been contracted elsewhere. Obviously, then, those who claim geographical immunity from the disease might do well to reappraise the local situation before denying its existence in any given area. It is really incredible that surgeons who inquire very meticulously into the specific cell type of a carcinoma should be so easily satisfied with the diagnosis, granuloma.

Thank you for the privilege of the floor.

DR. W. W. BUCKINGHAM, Kansas City, Mo. (Closing).—I wish to compliment Dr. Salyer on his excellent management of his case and on the outcome. This case bears out our contention that histoplasmosis has no respect for anatomic barriers and also that another pathologic entity, namey, vena caval syndrome and mediastinitis has been added to the list with histoplasmosis as the cause. I wish to thank Dr. Peabody for his discussion and his reference to the re-infection phases of this disease. We must also remember that this disease may be latent in its character and chronicity. There is a definite histoplasmosis belt running from Texas through the mid-central states and into Tennessee on the east. There has been a recent release from Washington by the Public Health Service to the effect that there is increasing evidence that the disease is being spread by tornadoes and may be airborne. If this proves true, there may be more outbreaks of the disease around the world and the differential diagnosis should be more thoroughly ruled out in all obscure pulmonary lesions. There is increased evidence that the fungus is activated by dark, damp, moist environments especially in chicken houses and, on several occasions, the fungus has been isolated from the droppings of bats and birds. These may be the hosts. There is no evidence that the disease may be transmitted from man to man.

A STUDY OF THE ROLE OF DRUG RESISTANCE IN THE SURGICAL TREATMENT OF PULMONARY TUBERCULOSIS

(JANUARY, 1947—JUNE, 1956)

WILLIAM R. SWEETMAN, MAJOR, MC, USA (BY INVITATION), AND
JOHN M. SALYER, COLONEL, MC, USA
DENVER, COLO.

THE IMPORTANCE of drug resistance in the medical treatment of pulmonary tuberculosis is well established. Its role in the surgical management is, however, not so well documented.

Holland, Bell, and Welles[1] reported recently that in 42 resections in which the tubercle bacilli were resistant at surgery, 14 or 33 per cent had major complications, although there were no operative deaths. They conclude that the presence of drug resistant organisms is the most important single factor in this increased morbidity. Further evidence is mentioned by Bell and Medlar[2] in a report concerning 8 cases of occult fistulas following partial lobectomy in which tubercle bacilli recovered from the resected specimens were resistant in 7. Only 3 of these patients had been positive prior to operation.

In 1951, Murphy and associates[3] compared their experience in operating on drug resistant patients with the experiences summarized in the Ninth Streptomycin Conference. In their series, they found that of 14 drug-resistant and 15 drug-sensitive patients operated upon, the bronchopleural fistula rate was twice as great in the resistant group, the empyema incidence was 39 per cent in the group harboring resistant bacilli compared with 30 per cent in the drug-sensitive group, and the postoperative spread rate was 29 and 20 per cent, respectively. The results in the Veterans Administration in a series of 56 resections with bacterial resistance and 120 with drug sensitivity, showed a 29 per cent bronchopleural fistula rate in the resistant group compared with 11 per cent in the sensitive group, an empyema rate of 27 and 12 per cent, respectively, and demonstrable spread in 30 as opposed to 11 per cent.

In studying their experience, however, Falk and Tucker[4] conclude that the factor of drug resistance did not lead to an increase in complications and mortality. Andrews and his associates[5] found that of 48 patients with far-advanced disease, 27 per cent had major complications compared with 13 per cent in the moderately advanced. Twenty-seven per cent of 51 patients in this study with drug susceptible organisms developed major complications, whereas, of 9 harboring resistant bacilli, 3 or 33 per cent incurred complications.

From the Department of Surgery, Fitzsimons Army Hospital, Denver, Colo.
Read at the Thirty-seventh Annual Meeting of The American Association for Thoracic Surgery at Chicago, Ill., May 4-7, 1957.

Wilson[6] suggested the importance of the extent and severity of the early disease process, or the failure of medical treatment, as perhaps more important factors than drug resistance.

In an effort to furnish further data and help clarify this problem, 1,061 consecutive resections for pulmonary tuberculosis performed at Fitzsimons Army Hospital during the period January, 1947, through June, 1956, have been reviewed[7] (Table I). Of this group, 46 resections in 44 patients were performed in the face of known drug resistance and positivity within 2 months prior to operation.

TABLE I. 1947–1956 (JUNE)

	OPERATIONS	MAJOR COMPLICATIONS	DEATHS
Wedge	167	2 (1.2%)	1 (0.6%)
Segmental resection	446	38 (8.5%)	4 (0.9%)
Lobe lobe	405	25 (6.2%)	5 (1.2%)
lobe + Pneumonectomy	43	11 (25.6%)	6 (13.9%)
Total	1061	76 (7.2%)	16 (1.5%)

The following are considered major complications: bronchopleural fistula, empyema, tuberculous spread, hemothorax and persistent spaces requiring reoperation, pneumonia, and cardiac arrest (Table II). The deaths are those due to postoperative complications.

TABLE II. MAJOR COMPLICATIONS REQUIRING REOPERATION

	NUMBER OF COMPLICATIONS	NUMBER OF REOPERATIONS
Segmental resection (5)	3	3
Lobe (24)	6	1
Lobe + (4)	1	1
Pneumonectomy (13)	6	1
Total (46)	16	6

In the entire group of 1,061 resections, the complication rate, as classified above, was 7.2 per cent and the operative mortality 1.5 per cent (Table III). In the resistant group the complication rate was 34.8 per cent and the mortality 10.9 per cent.

TABLE III

	NUMBER OF OPERATIONS	PER CENT COMPLICATIONS	PER CENT DEATHS
1947–1952	443	5.4	2.3
1953–1956 (June)	618	8.4	0.8
1947–1956 (June)	1061	7.2	1.5
46 resections in 44 resistant cases 1947–1956 (June)	46	34.8	10.9

When the cases are broken down into types of operations, it is noteworthy, as had been anticipated, that the greatest incidence of complications followed pneumonectomy (Table IV). Of 13 patients in this resistant series, 6 or 46.2 per cent developed major complications. This is in contrast to a complication rate of 25.6 per cent in all patients having total unilateral resections (11 of 43 patients who underwent pneumonectomy).

TABLE IV

	46 OPERATIONS IN 44 RESISTANT CASES			TOTAL EXPERIENCE 1947–1956 (JUNE)		
	NO. CASES	COMPLICATIONS (%)	DEATHS (%)	NO. CASES	COMPLICATIONS (%)	DEATHS (%)
Segmental resection	(5)	60.0	0.0	(446)	8.5	0.9
Lobe	(28)	25.0	10.7	(405)	6.2	1.2
Pneumonectomy	(13)	46.2	15.4	(43)	25.6	13.9

When lobectomy and lobectomy plus wedge or segmental resections are grouped together, it is seen that the complication rate in the resistant group was 25.0 per cent (7 of 28) as compared with 6.2 per cent in the total series (25 of 405). It is interesting to note that, in the resistant group, the complication rate is no higher in the lobectomy plus wedge or segmental resections than in simple lobectomy or bilobectomy, despite greater extent of disease and poorer risk (Table V).

TABLE V. 46 RESECTIONS IN 44 RESISTANT CASES

	NUMBER	PER CENT OF COMPLICATIONS		PER CENT OF DEATHS	
Segmental resection	5	(3)	60.0	(0)	0.0
Lobe	24	(6)	26.0	(3)	10.7
Lobe +	4	(1)	25.0	(0)	0.0
Pneumonectomy	13	(6)	46.2	(2)	15.4
Total	46	(16)	34.8	(5)	10.9

The 5 segmental resections performed in the resistant series represent too small a number for significant statistical analysis.

The mortality figures are of considerable interest (see Table IV). In the pneumonectomy group, those resistant carried an operative mortality of 15.4 per cent compared with 13.9 per cent in the entire series. In resistant cases, this is lower than one might expect. In the patients undergoing lobectomy in the treatment of resistant bacterial disease, the mortality was 10.7 per cent in contrast to 1.2 per cent in the total group. In the segmental resections there were no deaths compared with an over-all mortality of 0.9 per cent.

Since this experience dates back to an era of short periods of single drug treatment and includes cases not benefited by combined chemotherapy, it may be pertinent to analyze the cases done since 1953 (Table VI). A total of 618 resections were performed from January, 1953, through June, 1956, with a complication rate of 8.4 per cent and a mortality of 0.8 per cent. When the 18 operations, in the positive resistant group, performed during this period are analyzed, the complication rate is 33.3 per cent and there were no deaths.

Preceding the 5 postoperative deaths among the 44 positive resistant patients during the 9½ year study period, the following complications occurred: (1) a bronchopleural fistula 3 weeks after a left upper lobectomy led to empyema and a gradual downhill course with death after 4 months; (2) a contralateral spread in the immediate postoperative period following a right upper lobectomy led to pulmonary insufficiency and death from massive hemoptysis 5 months after operation; (3) empyema and wound dehiscence led to death

on the fifteenth day after pneumonectomy; (4) acute pulmonary congestion and edema led to death on the fifth day after pneumonectomy; (5) and sudden, unexpected death 2 days after an uneventful right upper lobectomy.

TABLE VI. PERIOD 1953–1956 (JUNE)

	NUMBER OF CASES	PER CENT OF COMPLICATIONS		PER CENT OF DEATHS	
1953–1956 (June)	618	(52)	8.4	(5)	0.8
1953–1956 (June) Resistant cases	18	(6)	33.3	(0)	0.0

DISCUSSION

It is evident from this study that the morbidity and mortality accompanying surgical resection in pulmonary tuberculosis are definitely increased in the positive resistant cases. Exceptions to this are in the mortality for pneumonectomy in which there was no significant difference from the total experience, and in the absence of deaths in the period of combined chemotherapy since 1953.

Although one is inevitably led to the conclusion that drug resistance is a factor of paramount importance in this observed increased morbidity and mortality, one must also consider that the type of case, as determined by age, degree and extent of pulmonary fibrosis and emphysema, the extent of the disease and the length of treatment or re-treatment are also of great importance in interpreting these results. Such an analysis reveals that all but 5 patients in the resistant group had far-advanced disease and that in 8 all lobes of both lungs were involved.

This fact suggests that the extent of disease, characterizing many of the patients as salvage cases, is fully as important as drug resistance. Our data do not support re-treatment as a more important factor than original treatment, since of the group experiencing complications, 7 were original and 5 re-treatment cases. Among those without complications 18 received original treatment and 9 were re-treated (Table VII).

TABLE VII

	ORIGINAL TREATMENT	RE-TREATMENT
With complications	7	5
	2 dead	2 dead
Without complications	18	9
		1 dead

It has been suggested that lobectomy is preferable to segmental resection in the positive resistant case.[1] If this tenet were followed in this series, 3 patients would have been denied surgery. Such far-advanced cases with limited pulmonary reserve tolerated segmental loss, but (in our opinion), would have been severe pulmonary cripples after lobectomy. Bacterial drug resistance in patients meeting the criteria for surgical excision is a formidable factor to be reckoned with. This study, however, does not substantiate the rather prevalent concept and opinion that lobectomy is preferable to segmental resection,

if such a limited resection is anatomically and technically feasible in such complex clinical problems. Although our experience is too small (5 segmental resections) to stand as proof, we believe that segmental resection in the positive resistant case carries little, if any, additional risk of complication or mortality as compared with lobectomy.

It should be noted that 37 of the 39 survivors in the resistant group are sputum negative and many have returned to duty or to their previous occupations.

SUMMARY

One thousand and sixty-one consecutive pulmonary resections for tuberculosis from January, 1947, through June, 1956, performed at Fitzsimons Army Hospital, have been studied in regard to major complications and postoperative mortality. Forty-six of these resections were done on patients who harbored resistant organisms prior to surgical excision. The results confirm the findings of most authors that drug resistance is an important factor in respect to increased morbidity and mortality. It is suggested, however, that type of patient and the extent of disease are perhaps as important. Such frequently associated factors make it impossible to draw irrefutable conclusions at this time.

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DISCUSSION

DR. JOSEPH GORDON, Albuquerque, N. M.—One of the other perhaps less frequent things that should be considered in evaluating material, particularly during a chemotherapeutic program, is whether or not the residue of disease that one may find after long term chemotherapy represents cavities or cysts within the lung. We have this program under study at the Albuquerque Veterans Hospital. In our long experience with bronchography, we have the impression now that it is extremely difficult to have the contrast medium enter into the tuberculous cavity in treated, as well as untreated, cases.

As can be seen in this slide, there is a good outline of the bronchi in the right lung. Efforts to have the contrast medium enter the cavity are without success. It is believes that this is related to the fact that the contiguous draining bronchus is regularly involved by the disease and has undergone narrowing and tortuosity making it difficult for the contrast medium to enter the cavity.

As seen in this slide in a cyst within the lung, the contrast medium enters readily into the cavity and there is no difficulty in demonstrating it.

In another case the patient had a positive sputum for tuberculosis. In this slide we see many crescent shadows presumably representing multiple cavities. After pneumonectomy it was noted that there were many small cysts in the lung. The only place in which there was tuberculosis was in a pneumonic patch in the superior segment of the lower lobe, the remaining portion of the lung being quite clear of the disease. The diagnosis of tuberculosis with multiple residual cavities was not entirely accurate, but rather cystic disease and tuberculosis.

In still another case, we had the good fortune of having the patient's films taken some years before the advent of tuberculosis, showing a relatively normal film. This fits in well with the discussion this morning about following the course of the disease from earlier films.

In the next slide there is evidence of tuberculosis as demonstrated by positive sputum. The following slide shows that there is clearing of most of the disease in the midlung field, with a thin-walled shadow in the base.

This next slide is a little bit more representative of the annual shadow in the planigraphic film. Following this, bronchograms were made. In the next slide, we see that there is easy ingress of the contrast medium into the cavitary area. With removal of this lung, the only place that had any evidence of tuberculosis was in the apical-posterior segment of the upper lobe and in the remaining portion was cystic disease.

We believe that the anlage of cystic disease of the lung may be inherent. As has been seen several times today, apparently with the advent of superinfection, whether it be tuberculous, pyogenic or fungous disease, cyst formation is seen to develop.

This, I believe, is worthy of further study so that we can determine whether or not there are patients who have cystic deasease with residue of the primary infection.

DR. ROBERT KLOPSTOCK, Brooklyn, N. Y.—(This discussion was not returned.—EDITOR.)

DR. WARRINER WOODRUFF, Saranac Lake, N. Y.—I have been asked to present the material from the Veterans Administration Hospital at Sunmount, as neither Dr. Decker nor Dr. Wade are able to be present.

In general, the Sunmount results are similar to those of Dr. Sweetman and Dr. Salyer, in that of 47 patients subjected to resection without any effective drug coverage, approximately 30 per cent, either developed early complications or had late unsatisfactory results.

This Sunmount study is based upon 124 patients, who were subjected to resection between January, 1950, and the middle of 1956. It includes only those patients who, at the time of operation, had open cavities and also had a positive sputum culture within 3 months of operation. All these patients were under chemotherapy and most had developed resistance to at least one drug and, accordingly, in certain series would be regarded as "drug resistant."

RESULTS OF RESECTION CORRELATED WITH POSTOPERATIVE CHEMOTHERAPY

90 DAYS POSTOPERATIVE			6 MO. TO 6 YR. POSTOPERATIVE	
NUMBER EFFECTIVE DRUGS	NUMBER OF CASES	EARLY TBC COMP.	NUMBER OF CASES	LATE UNSATISFACTORY RESULTS
2	40	3 (8%)	35	0 (0%)
1	20	3 (15%)	19	0 (0%)
0	47	13 (28%)	45	14 (31%)
VIO + TM, PZA, PAS*	17	2 (11%)	12	2 (17%)
Total	124	21 (17%)	111	16 (14%)

*Viomycin + Terramycin, pyrazinamide, para-aminosalicylic acid.

From the table which will be appended, it will be seen that the number of drugs to which a patient's organisms are resistant is much less important than that there still be drugs to which the organisms are sensitive.

In this series, streptomycin, PAS, and viomycin were considered effective only if there were *no growth* of the preoperative cultures in concentrations of 10 mcg. per milliliter. When INH was tested the concentration used was 1 mcg. per milliliter.

The surprisingly good results of single drug "effective" coverage refers only to streptomycin or INH, and perhaps reflects the ability of these drugs to control noncavitary disease, the cavities having been removed surgically. Combined therapy based on viomycin continues to appear more useful as surgical coverage than as a basic treatment regimen, and therefore early resort to resection is indicated whenever feasible with such regimens.

It would seem that these studies support the following conclusions:

1. "Drug resistance" is not a particularly serious handicap as long as other "effective" drugs remain to protect the patient during and after surgery.

2. It is unwise to use all effective drugs in the hope of obtaining a negative sputum, because if such a program fails, the incidence of complications with surgery is high.

3. If, after a trial of drug therapy, conversion seems unlikely, early surgery should be undertaken while adequate protection can be afforded by effective drugs.

DR. JOHN M. SALYER, Denver, Colo. (Closing).—I should like to thank Dr. Gordon, Dr. Klopstock, and Dr. Woodruff for discussing this paper. As we did this study we realized that more and more factors were involved. Of course, we had to rely heavily on statistics. The findings after a study of such a large series should be significant but, nevertheless, figures at times cause doubts. At St. Louis, this February, the Veterans Administration–Armed Forces symposium on chemotherapy in tuberculosis reported, for last year, 17 pulmonary resections in the treatment of tuberculosis in patients over 60 years of age. They had no significant complications and no deaths in this group; thus, sometimes statistics are difficult to reconcile.

I would like to present a case briefly to point out some of the problems that may be peculiar to a single patient who ultimately becomes bacterially resistant. A woman, 30 years of age, had a right upper lobectomy at Fitzsimons Army Hospital in 1952, for treatment of pulmonary disease present since 1946. She was found to have tuberculosis at the time her father died of the disease. (slide) There is fibrosis throughout both lungs. Shortly after resection it was noted that she had cavity in the superior segment of the left lower lobe. At this time she had a vital capacity of 1,400 c.c. and an MBC of 45. After being treated with pneumoperitoneum for almost a year her sputum became negative and she was discharged. She again became positive in 1954 and was treated elsewhere with various antituberculosis regimens until late in 1956. At this time the cavity on the left had not changed significantly. The remaining pulmonary segments seemed to be free of active disease. Her pulmonary reserve and function had not improved. However, we felt we should do something for her surgically if possible, as she was now resistant to two of the major antituberculosis drugs. We sent her to physical therapy for breathing exercises. Over a 2 months' period, they increased the vital capacity from 1,300 to 1,600 c.c. and the MBC from 45 to 60. Split functions (O_2 consumption and vital capacity) were approximately equal on each side. At this time we performed a segmental resection of the cavitary superior segment. Four days prior to the segmental resection a pneumoperitoneum was instituted to assist in closing the pleural space following resection. (slide) This is 9 weeks after surgery and she has done extremely well. This, then, is an example of a re-treated, bacterial resistant patient with extremely poor ventilatory function who has so far not had additional complications after a segmental resection.

I would like to say that many doctors were involved in this surgery at Fitzsimons. Colonel Forsee, Dr. Bob Major, and Dr. Paul Ware, who are in the audience today, did a great deal of this work; in fact, about 40 surgeons performed this surgery. Dr. Sweetman and I have supervised and performed some of it. We have learned much from these fine surgeons and from others, and I wish to thank them all for helping us in this work.

THE VALUE OF ROUTINE PULMONARY FUNCTION STUDIES IN THORACIC SURGICAL CASES

Results in 212 Cases

Hurst B. Hatch, Jr., M.D. (by invitation), J. K. Bradford, M.D. (by invitation), and Alton Ochsner, M.D.
New Orleans, La.

DURING the past decade there has been an increase in the use of physiologic tests to analyze pulmonary function in normal persons as well as in patients with pulmonary disease. Information obtained in this way should, of course, supplement and never supplant that derived from a careful history, physical examination, and other diagnostic studies. One need only review the clinician's evaluation of the ability of patients to withstand certain surgical procedures, prior to the advent of specific methods of measurement of pulmonary function, to appreciate how remarkably accurate such an evaluation can be. The limitations of pulmonary function studies, however, must be recognized. For example, they cannot yield a histologic diagnosis, nor can they recognize the slight reduction in functioning pulmonary tissue that might result from an early peripheral carcinoma or from any other cause.

On the other hand, routine study of pulmonary function in patients with pulmonary disease is more than justified, since there are patients in whom significant abnormalities will be discovered by these tests even though results of clinical studies are negative or equivocal. Detection of such physiologic abnormalities is of great importance in a specific patient, regardless of the type of therapy contemplated. These tests also provide quantitative evidence of progression or regression of disease.

Dyspnea, the major symptom of ventilatory insufficiency, is one of the most difficult complaints to evaluate clinically. Because of the wide variation in the threshold of this symptom in different patients, it is possible for a patient to have severe pulmonary disability with minimal pulmonary insufficiency, or vice versa. Cyanosis and fatigue, evidences of a respiratory defect in pulmonary function, are also most difficult to evaluate clinically. For example, a discrepancy has always been noted in comparative studies on the clinical recognition of cyanosis and the arterial oxygen saturation.

Study of pulmonary function assumes even greater importance in patients with bronchogenic carcinoma. In these older patients, either because of the

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process of aging or a complicating disease unrelated to the carcinoma, particularly obstructive emphysema, pulmonary function may be significantly abnormal. The objective findings delineating the type and severity of pulmonary insufficiency are extremely helpful in determining the proper therapeutic procedure for an individual patient. Often, the symptoms of a superimposed or associated disease have been ascribed to the tumor and, with false security, the patient has been assured that proper therapy directed to the tumor will alleviate the symptoms. Also, by these tests a primary respiratory defect has been detected in patients with minimal or no symptoms and treatment instituted at a stage of the disease when therapy could be most effective.

The necessity for treatment of a complicating disease before the patient is subjected, for example, to a thoracic operation is obvious. Through the years we have been impressed with the fact that complicating diseases can be adequately treated and then proper therapy successfully directed to the primary problem, when this would not have been possible if the complication had not been first resolved.

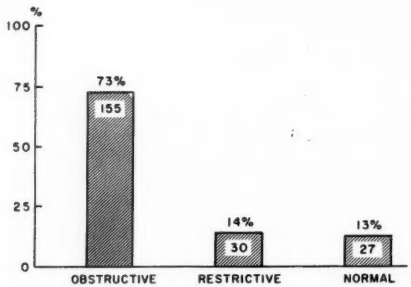

Fig. 1.—Types of pulmonary insufficiency in 212 candidates for thoracic surgical procedure.

A group of tests is available to measure objectively both divisions of pulmonary function: (1) ventilation, the mechanical component, and (2) respiration, the physiochemical component. For complete analysis of pulmonary function both phases should be measured.

Our experience with pulmonary function studies consists of 212 cases. This includes every patient admitted to Ochsner Foundation Hospital on whom a thoracic surgical procedure was contemplated during 1955 and 1956. Pulmonary function was determined by the standard procedures. Ventilatory function was measured by the vital capacity, timed vital capacity, combined spirometry, and maximum breathing capacity. Residual air was determined by the open circuit technique of Darling and co-workers.[1] The respiratory aspect of pulmonary function was evaluated by determination of oxygen and carbon dioxide tensions of one or more specimens of peripheral arterial blood by the method of Filley and associates.[2] Additional studies, such as A-A gradient and oxygen diffusion capacities, carbon monoxide diffusion capacities, and bronchospirometry, were done when deemed advisable.

Of the 212 patients, 27 (13 per cent) had normal pulmonary function (Fig. 1). Ninety-five per cent of these were 45 years of age or younger. Fifty per cent of the entire series had an abnormality of respiratory function, as indicated by reduction of arterial oxygen tension to a hypoxic level. In no patient was there evidence of carbon dioxide retention.

Some degree of obstructive ventilatory insufficiency was present in 155 patients, or 73 per cent of the entire series (see Fig. 1). This incidence may at first seem strikingly high. However, as has been demonstrated in our laboratory, the older a patient is, the greater the degree of change in the ventilatory mechanism. In our patients this change has usually been of an obstructive nature. The explanation of this high incidence of obstructive ventilatory insufficiency may lie partly in the fact that 85 per cent of the patients in this series were 45 years of age or older. Moreover, such obstructive changes may well result from the disease itself, and with its removal, a significant amount of insufficiency may prove to be reversible. Finally, obstructive emphysema is prevalent in patients of this age group.

In the present series, 26 patients had results of pulmonary function studies compatible with a diagnosis of obstructive pulmonary emphysema (Fig. 2).

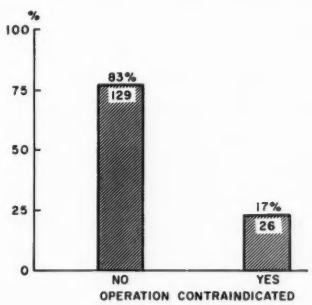

Fig. 2.

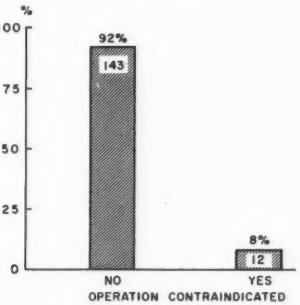

Fig. 3.

Fig. 2.—Obstructive insufficiency in 155 patients; distribution before rehabilitation.
Fig. 3.—Obstructive insufficiency in 155 patients; distribution after rehabilitation.

This represents 12 per cent of the total series or 17 per cent of the 155 patients found to have some type of obstructive insufficiency severe enough to make thoracotomy hazardous. Of these 26 patients, 14 (53 per cent) were sufficiently rehabilitated by use of bronchodilators, expectorants, and breathing exercises so that some type of excisional or reparative surgical procedure could eventually be accomplished (Fig. 3).

Operation was performed in the remaining 129 patients with obstructive ventilatory insufficiency. Some of these had concomitant treatment of the ventilatory insufficiency and others did not. It is often in this group that the pulmonary dysfunction is due to the primary surgical problem within the thorax. The surgical procedure, therefore, will result in complete reversal of the basic physiologic abnormality.

Thirty (14 per cent) of the 212 patients had evidence of a predominantly restrictive type of ventilatory insufficiency with or without some minimal respiratory abnormality (Fig. 4). Twenty-two of these 30 patients had insufficient diminution in pulmonary function to contraindicate surgical treatment; in the other 8 the reduction in pulmonary function was sufficient to make operation seem inadvisable. Five of these 8 patients had severe pulmonary fibrosis. The remaining 3 had slight restrictive ventilatory insufficiency with evidence of a definite diffusion block but no clinical evidence suggestive of such a defect. However, biopsy of the lung with use of a local anesthetic definitely confirmed the suspected abnormality in the alveolar capillary membrane. Thus, by the pulmonary function tests a distinct process from that for which the thoracotomy was originally deemed advisable was demonstrated.

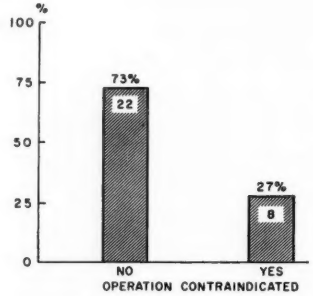

Fig. 4.—Restrictive insufficiency in 30 patients.

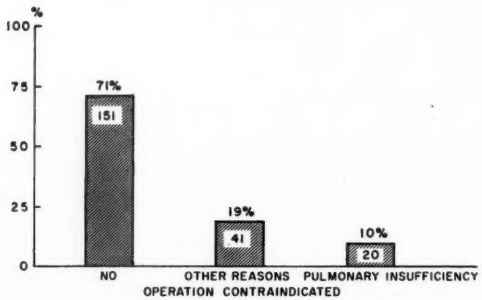

Fig. 5.—Disposition of 212 thoracic surgical candidates.

In the entire series, 71 per cent (151 patients) had a surgical procedure consisting of at least a thoracotomy, in 10 per cent operation was contraindicated because of definite pulmonary insufficiency and in 19 per cent (41 cases) operation was not performed for various other reasons (Fig. 5).

In the 212 patients only 0.9 per cent of the deaths could be ascribed to pulmonary insufficiency. It is true that some other patients in this series do

have pulmonary disability, but this is not enough to interfere with their usual daily routine. The mortality rate from other causes was 13 per cent during a follow-up postoperative period of slightly more than 2 years.

Just what do these statistics indicate? We believe that three things can be accomplished by preoperative performance of pulmonary function studies. First, knowledge of the basic physiologic pulmonary normalcy or abnormality of patients enables us to treat any associated disease more adequately and thus makes the operative and postoperative courses of these patients smoother. Second, a significant percentage of patients is sufficiently rehabilitated to permit performance of the indicated surgical procedure. And finally, we are able to ascertain the presence of disease, particularly diffusion defects, that were not suspected clinically and that might result in disaster if operation were performed.

CONCLUSIONS

Both morbidity and mortality rates as a result of postoperative pulmonary insufficiency are decreasing as we become more aware of the value of analysis of pulmonary function in candidates for thoracic surgical procedures. We cannot stress too much the importance of these studies and believe that they should become an integral part of the routine preoperative evaluation of such patients. The results of this study would seem to indicate the importance of pulmonary function tests. However, unless the results are properly interpreted, such studies are of little value.

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DISCUSSION

DR. ALLEN STRANAHAN, Albany, N. Y.—(This discussion was not returned.—EDITOR.)

DR. W. S. BLAKEMORE, Philadelphia, Pa.—We also have recognized the importance of preoperative evaluation of pulmonary function for a number of years. However, the laboratory tests which have been described in this paper would require the full time of a fairly large laboratory staff, especially if there are many patients on the thoracic surgical service. We have, therefore, made an effort to screen patients in order to determine which need these extensive pulmonary function studies and which do not. For this purpose we have used three simple tests which can be done as part of the routine clinical examination at the bedside. One of these is measurement of the vital capacity by the use of a small bellows which is available commercially. The second is the measurement of the maximal breathing capacity using a portable apparatus based on the Venturi principle which we designed some 4 years ago, and which can be easily used by the interne to measure the maximal breathing capacity. This measurement can readily be rechecked if the value is low and it is almost impossible to obtain high values with this apparatus. The third screening test is that of walking up the stairs, to determine the physical stamina and fitness. It also seems appropriate to determine the arterial CO_2 tension, because this value provides some evaluation of the over-all function of the lung. It should be measured if

the other screening tests suggest that pulmonary insufficiency may be present. In addition, we have developed with the group of Dr. Julius Comroe, Jr, over a period of 8 years, pulmonary function tests for detecting abnormalities of a more specific nature. We have tried to simplify additional tests and not all are practical for routine use for every patient. A single breath test for detecting mixing abnormalities is included in these tests. We have devised a single breath test for measuring the diffusion capacity of the lung using carbon monoxide, but in general the battery of tests is not needed for each individual patient. Pulmonary insufficiency is now recognized as a postoperative problem. Probably the greatest contribution of these physiologic tests is, as indicated by Dr. H. Maier a number of years ago, that they provide a better understanding of physiologic principles involved in the practical management of these patients.

DR. JOHN W. STRIEDER, Boston, Mass.—We are, for the most part, in agreement with the excellent paper of Dr. Hatch and his associates. Our experience is much the same in something over 3,000 studies we have done routinely at the Boston City Hospital. We have found two things that have seemed significant to us. First, in about 10 per cent of the cases one can be so wrong in his clinical estimation of the pulmonary status that this would seem to give added weight to the advisability of screening all patients by the simple laboratory function studies that are best adapted to the group in which they are done. Second, that if one is looking for a figure on which to hang one's hat as to what constitutes operability and inoperability, there is no absolute figure which fits every case. In some 500 cases that Dr. Gaensler studied with the idea of determining the role of pulmonary insufficiency as it affects mortality and morbidity, the patients who had a maximum breathing capacity which was 50 per cent of normal or less, had an operative mortality of 50 per cent when we were so ill-advised as to do major pulmonary surgery on this group. However, if, for example, a patient has a maximum breathing capacity of 50 per cent of normal, contributed by one lung as shown by bronchospirometry, other things being equal such a patient may well be a suitable candidate for surgery.

DR. HURST B. HATCH, New Orleans, La. (Closing).—I have nothing to add, but I wish to thank all the discussants very much as I am sure Dr. Ochsner does also.

HYPOPLASIA OF THE LOBAR PULMONARY ARTERIES

A Report of Three Cases

J. R. Belcher, M.S., and J. N. Pattinson, M.B.
London, England

A WIDE variety of abnormalities of the pulmonary blood vessels have been described, but we have been unable to find any recorded examples of hypoplasia of the lobar arteries as an isolated anomaly similar to the 3 cases reported here.

In agenesis of a lung the pulmonary artery is always absent on the ipsilateral side. The right or left pulmonary artery may also be completely absent even in the presence of otherwise well-developed pulmonary tissue. The literature relating to the latter anomaly has recently been reviewed (Emanuel, and Pattinson[1]). Absence of a lobar pulmonary artery occurs with lobar agenesis of the lung (Morton and others[2]), or even the whole pulmonary artery may be absent on the affected side in such cases (Findlay, and Maier[3]). Hypoplasia of a lobar artery has been described by Smith,[4, 5] McDowell and others,[6] in association with intralobar sequestration. In such cases the presence of an aberrant artery arising from the dorsal aorta and entering the sequestrated segment forms an additional vascular anomaly. Maier[7] described 2 cases of hypoplastic unilobar right lung with a small right pulmonary artery in which aberrant systemic vessels from the dorsal aorta were also found entering the lobe.

CASE REPORTS

Case 1.—H. P., a man aged 35, had had recurrent attacks of bronchitis and pneumonia since childhood; recently he had become dyspneic. A radiograph (Fig. 1) showed increased radiolucency of the whole left lung, and a cyst was visible at the base. Bronchograms (Fig. 2) showed gross bronchiectasis of the lower lobe and of the lingula. At operation both these lobes were shrunken, but not airless. The lower lobe was markedly emphysematous and a deep intersegmental fissure was present. The lower lobe artery was a third of normal size (5 mm., external diameter) and that to the lingula only slightly smaller than usual. The bronchial arteries were enlarged; there were no aberrant vessels (Fig. 3).

Comment: In this patient the vascular anomaly was recognized at the time of the operation. Although this may represent an extreme example of shrinkage of the artery following the development of bronchiectasis, the authors are of the opinion that the primary abnormality was arterial and that the bronchiectasis was secondary to it.

Case 2.—E. S., a woman aged 27, had an eighteen-year history of bronchitis and of productive cough. A radiograph (Fig. 4) showed an area of increased radiolucency at the right base and a bronchogram demonstrated mild bronchiectasis of the middle and right

From The London Chest Hospital.
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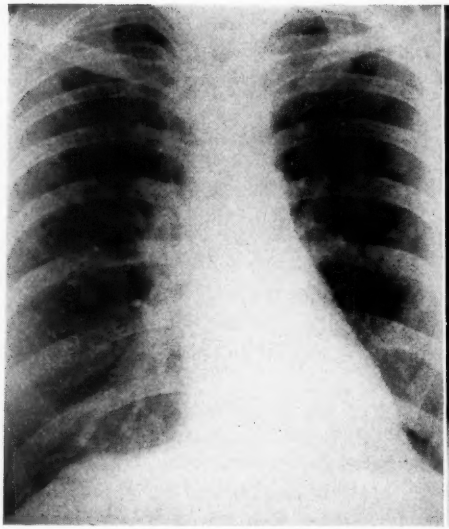


Fig. 1.

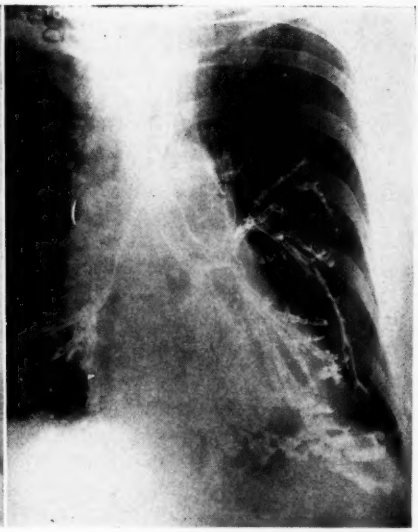


Fig. 2.

Fig. 1.—Case 1. Radiograph showing increased radiolucency on the left side with mediastinal shift in the same direction.

Fig. 2.—Case 1. Bronchogram showing gross bronchiectasis of the left lower lobe and lingula.

Fig. 3.—Case 1. The specimen with a probe in the small lobar artery. Emphysematous degeneration and the abnormal intersegmental fissure can also be seen.

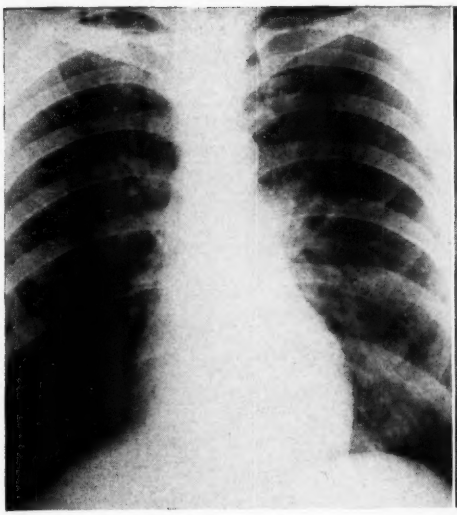


Fig. 4.

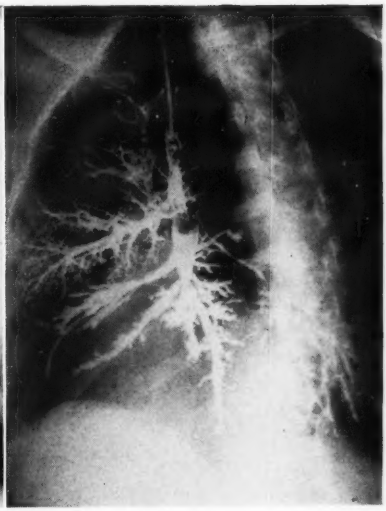


Fig. 5.

Fig. 4.—Case 2. Radiograph showing increased radiolucency at the right base.

Fig. 5.—Case 2. Bronchogram showing the unusual distribution of the right lower lobe bronchi and the "budding" along their course.

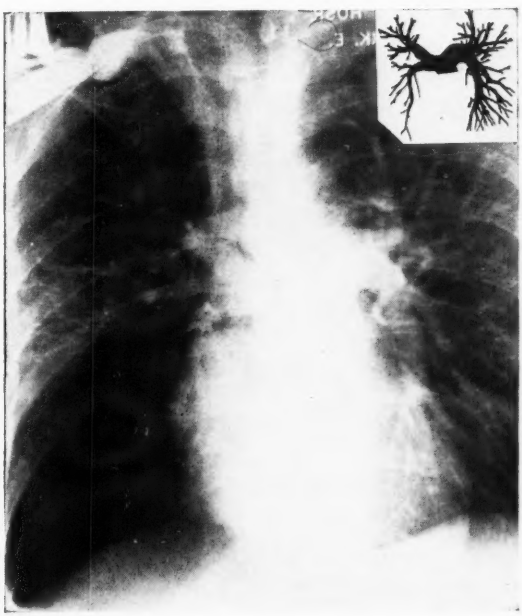


Fig. 6.—Case 2. Angiogram with a tracing of the pulmonary arteries (inset). It can be seen that the lower and middle lobe arteries are abnormally small.

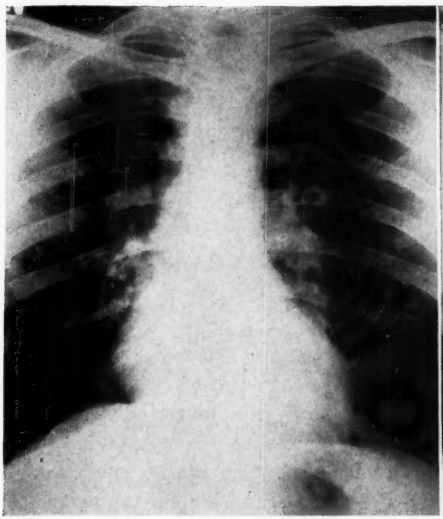
lower lobes, with a very abnormal distribution of the lower lobe bronchi (Fig. 5). Bronchoscopy showed no abnormality but on angiography the middle and right lower lobe arteries appeared very small (4 mm., internal diameter) (Fig. 6). At operation, the lower lobe was found to have abnormal fissures which followed the divisions of the bronchi shown on the bronchograms. The lobe was emphysematous but smaller than normal, and the lobar artery was greatly reduced in size, being no larger than the vessel which normally supplies the apical segment (5 mm., external diameter) (Fig. 7). There were no aberrant vessels.

Comment: In this patient, the experience with Case 1 led to fuller investigation, and hence to the preoperative diagnosis of the anomaly. The complete syndrome of an excessively radiolucent lobe occupying less space than normal, with bronchiectasis of an unusual type, was present.

Fig. 7.—Case 2. The specimen with a probe in the small right lower lobe artery. The emphysematous degeneration of the basal segments and the abnormal intersegmental fissures are also visible.

CASE 3.—P. G., a man aged 19, was found on routine radiography to have increased radiolucency at the right base (Fig. 8). Bronchoscopy and bronchography (Fig. 9) demonstrated crowding and minimal dilatation of the right lower lobe bronchi. On angiography the right lower lobe artery was very small, having an internal diameter of 7 mm. (Fig. 10). Bronchospirometery showed that although the ventilation on the right side was as great as that on the left, the oxygen uptake was considerably diminished. In the complete absence of symptoms, surgery was not contemplated.

Comment: In this case the diagnosis was presumptive, in that there was no pathologic confirmation, but the findings at bronchoscope, angiography, and bronchospirometery seemed unequivocal.



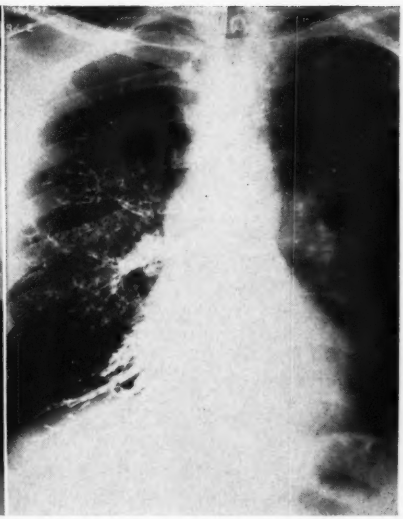


Fig. 8.

Fig. 9.

Fig. 8.—Case 3. Radiograph showing increased radiolucency at the right base.

Fig. 9.—Case 3. Bronchogram showing dilatation of the right lower and middle lobe bronchi. These lobes occupy a much smaller space than is normal.

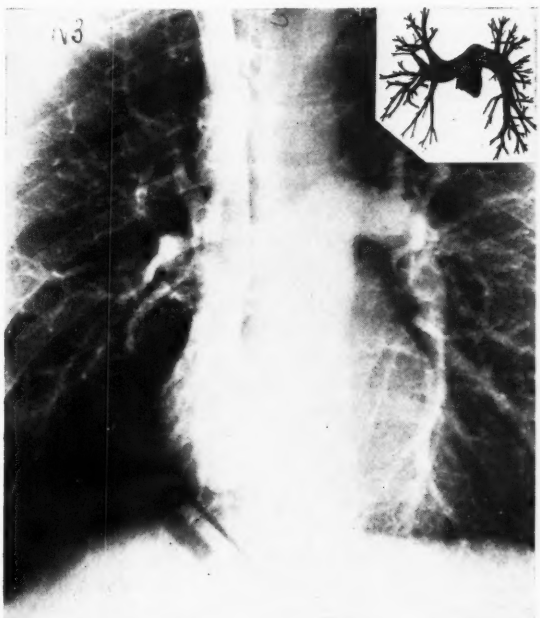


Fig. 10.—Case 3. Angiogram with a tracing of the pulmonary arteries (inset). The right lower lobe artery is much smaller than normal.

DISCUSSION

In each of the cases presented the clinical picture was similar. The affected lobe showed increased radiolucency, but occupied less space than normal. Bronchial abnormalities were present in all 3 patients; in one there was gross bronchiectasis, in another the bronchi were abnormal in distribution and showed buds along their course, and in the third there was a minor degree of bronchial dilatation. In 2, there was an additional congenital anomaly in the form of persistent intersegmental fissures. The lower lobe artery on the affected side was very small, measuring 4 and 7 mm. in diameter, respectively, in the 2 patients in whom angiocardiography was carried out, and was 5 mm., external diameter, in both the patients operated upon.

The essential cause of an increase in radiolucency in part of a lung is the diminution in the size and number of the vascular markings. This may be due to a variety of causes. Where a "check valve" mechanism is operating, as in cases of foreign-body or of bronchial tumor, the area concerned becomes distended and so occupies more space than normally, often causing mediastinal displacement. Under these circumstances the vascular markings become spread out and hence there is an increase in radiolucency. In local emphysema, which is also often associated with mediastinal displacement, the density of vascular markings is decreased for the same reasons and also because of a real loss of the smaller pulmonary vessels. Increased radiolucency of a lobe of normal size has been described by Westermark,[8] and by Shapiro and Rigler,[9] in cases where pulmonary embolism without infarction has occurred. The vascular pattern is well marked proximal to the embolus, whereas distally the lung shows increased radiolucency. Kjellberg and Olsson,[10] however, have failed to confirm these observations experimentally.

In cases where the right or left pulmonary artery is congenitally absent, such as that described by Smart and Pattinson,[11] the lung concerned is almost always smaller than usual. Emphysema may be present in the sense that there is interalveolar breakdown. This phenomenon of emphysema in pulmonary tissue, which occupies less space than is normal, is also seen in these cases of hypoplastic lobar arteries.

Reduction in the size of a lung or lobe occurs when it is bronchiectatic. This is frequently accompanied by some decrease in size of the pulmonary artery supplying the affected segment. Björk[12] showed that the pulmonary artery diminished in caliber in chronic atelectasis, but he did not observe a reduction in size beyond 60 per cent of the normal. In our 3 cases the lobar artery was only 30 per cent of the normal caliber.

There is also a diminution of flow in atelectatic lobes. This has been demonstrated on angiography by Scarini[13] and by others. Liebow and others[14] have shown that the bronchial arteries enlarge in chronic bronchiectasis. In general this enlargement is in direct proportion to the diminution in size of the pulmonary artery. In Case 1, the bronchial arteries were enlarged to the extent which might have been anticipated from the degree of infection present in the

affected lobe, but in Case 2 there was no such enlargement, and the extent of the bronchiectasis was too small to have caused any appreciable diminution in the size of the lobar artery.

Bronchial abnormalities were present in all 3 cases, and, in 2, there was superadded infection. We believe that this suppuration was not a primary phenomenon, but that it developed in a congenitally abnormal lobe. Steinberg and others[15] described a case of gross bronchiectasis in which the pulmonary artery on the affected side failed to fill on angiography. They were of the opinion that the vascular abnormality was secondary to the pulmonary lesion. We believe that, on the contrary, the pulmonary lesion was secondary to the congenital absence of the left pulmonary artery, and that this confusion of cause and effect may well be responsible for the fact that the entity presented in this paper has not been described before.

Hypoplasia of a lobar artery has been described in association with intralobar sequestration. In our experience, angiography in such cases demonstrates only a moderate decrease in size of the lobar artery, but a prominent reduction in the size and number of its peripheral branches. This is illustrated in the angiogram published by Smith[5] and is due to the failure of the pulmonary artery to supply the sequestrated segment. The latter receives an anomalous arterial supply from the dorsal aorta. In the 2 patients who were operated upon, a search was made for anomalous arteries and none were found. The lobar arteries were much smaller than appears to occur in sequestration. We believe that these cases represent a difference in pathology rather than in degree.

Macleod[16] described a group of 9 cases in which there was unusual transradiancy of the lung fields and commented on the appearance of loculi of oil in what appeared to be bronchial buds shown on the bronchograms. These were very similar to those seen in Case 2. In 4 of his patients the abnormality was confined to one lobe. There can be little doubt that these cases were examples of the entity presented in this paper, but as there was no material in which to study the morbid anatomy, the association of the conditions with an anomaly of the lobar artery was not suspected.

In order to establish a diagnosis of hypoplasia of a lobar artery, angiography may not be enough, for, as in the cases of Swyer and James,[17] the pulmonary artery may fill poorly, even if it is of good caliber, when there is little or no flow through it. The finding of an emphysematous, though small, lobe is not diagnostic, as this combination may be seen in simple bronchiectasis. Where, however, little or no bronchial dilatation is present in an emphysematous lobe which is smaller than normal and, more especially, where bronchospirometry shows diminished oxygen uptake despite normal ventilation, then angiography, by demonstrating great diminution in the size of a lobar artery, can confirm the diagnosis in a way that no other preoperative investigation can.

SUMMARY

1. Three cases of hypoplasia of lobar arteries are reported. These are believed to be congenital in origin.

2. Abnormal radiolucency of a lobe which occupies less space than normal, with bronchial abnormalities, a small lobar artery, and low oxygen uptake with normal ventilation form the complete syndrome.

3. No one investigation is sufficient to establish the diagnosis. Bronchography, bronchospirometry, and angiography may be required.

We are grateful to Dr. Sleigh Johnson and Dr. J. Smart for permission to publish the details of Cases 2 and 3.

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BRONCHOSPIROMETRY IN LATERAL DECUBITUS POSITIONS AND IN CLINICAL PRACTICE: SURVEY OF THE VENTILATORY EFFICIENCY

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MADRID, SPAIN

VARIOUS authors have interested themselves in the study of the mechanism of breathing and, by using bronchospirometry in the lateral decubitus position, they have found better ventilation in the lung in the subjacent hemithorax. The first one to observe this was Björkman of Stockholm, among others, although only a few have done so since then. It is surprising to find in some papers the assertion that this is inexplicable, although some writers have accurately defined the cause of the phenomenon.

We have studied this problem in the hope of getting to understand some facts which are not perfectly clear. The most important of these is that which relates to the increase of ventilatory efficiency as a mechanism compensating for the decrease in functioning parenchyma, which occurs as a consequence of pulmonary lesions, or as the result of surgical operations on the thorax.

However, we found some apparently contradictory facts which, most probably, appear contradictory only because we lack sufficient data to arrive at a correct explanation. Thus, for instance, we shall see presently that very frequently the ventilatory efficiency (i.e., the amount of oxygen absorbed per liter of ventilated air) is greater in patients in whom ventilation is decreased to certain limits, whereas in other observations (though less frequent) the exact opposite occurs.

Let us begin with a survey of the curves resulting from examination in the lateral decubitus position. The authors who have dealt with this subject point out that ventilation and ventilatory efficiency are greater in the subjacent lung. Charts 1 and 2 show the analysis of an ordinary case in which bronchospirometry was performed in the lateral decubitus position. The patient was a man, 31 years of age, with a fairly symmetrical thorax, affected with an ulcerative infiltrating lesion of slight density in the subclavicular area of the left lung. There was also a very slight symphysis in the bottom of the right costophrenic angle. There was no marked limitation of diaphragmatic motility on this side, although it was slightly inferior to that on the left side (Fig. 1). Global spirometry furnished some information which corresponded fairly closely to the sum of the data furnished by bronchospirometry.

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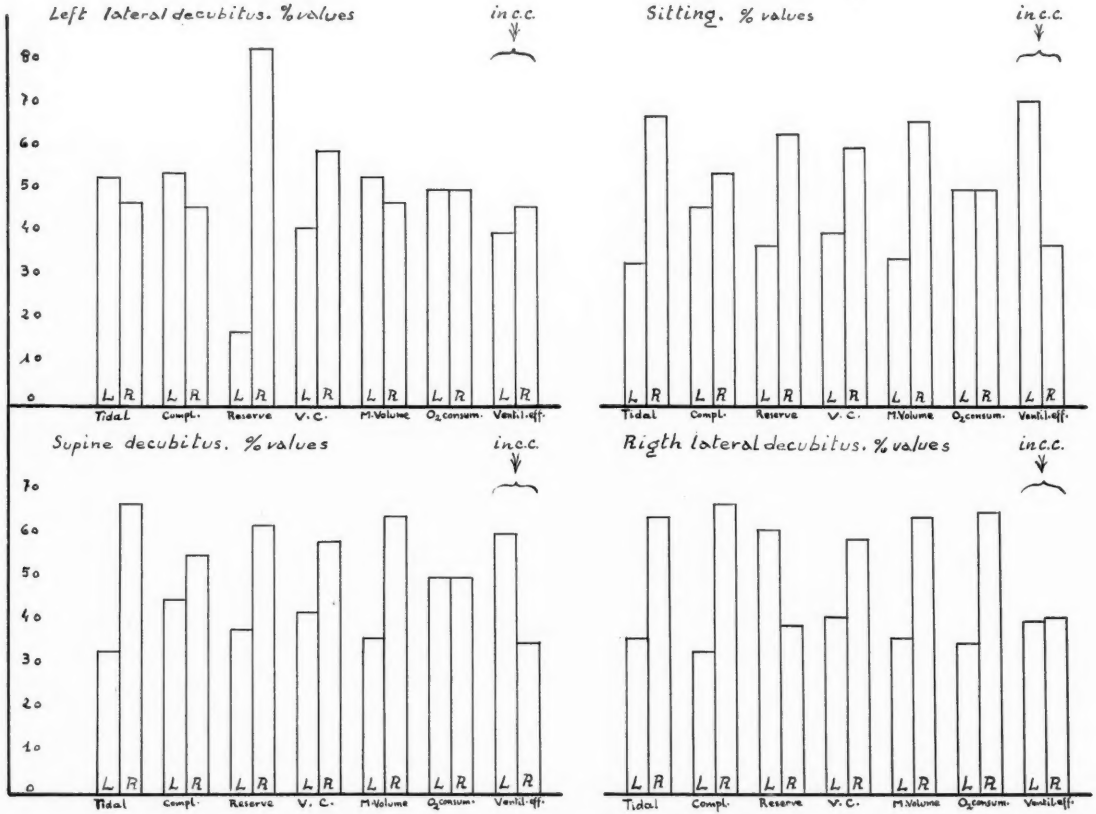

Chart 1.—Relative values of both sides in the different decubitus positions.

Supine Decubitus.—(Chart 1 and Table I show the percentage values for each side. Table II and Chart 2 show the absolute values.)

TABLE I. BRONCHOSPIROMETRY IN THE DECUBITUS POSITION (PER CENT VALUES OF BOTH SIDES)

	SUPINE		RIGHT LATERAL		LEFT LATERAL	
	L. LUNG	R. LUNG	L. LUNG	R. LUNG	L. LUNG	R. LUNG
Tidal air	33	67	36	64	53	47
Complementary air	45	55	33	67	54	46
Reserve air	38	62	61	39	17	83
Vital capacity	42	58	41	59	41	59
Minute volume	36	64	36	64	53	47
O_2 consumption	50	50	35	65	50	50
Ventilatory efficiency (c.c.)	59.5	32.8	40	40.9	39.7	45.7

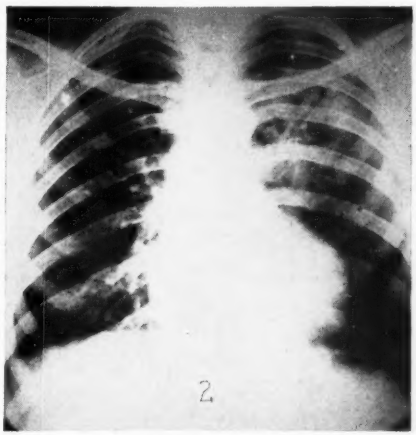

Fig. 1.—X-ray of patient in whom bronchospirometry was performed in the decubitis position.

TABLE II. ABSOLUTE VALUES IN CUBIC CENTIMETERS OF THE VENTILATORY FRACTIONS ON BOTH SIDES IN THE DIFFERENT DECUBITUS POSITIONS

	SUPINE		SITTING		LEFT LATERAL		RIGHT LATERAL	
	L. LUNG	R. LUNG	L. LUNG	R. LUNG	L. LUNG	R. LUNG	L. LUNG	R. LUNG
Tidal air	100	200	100	200	200	175	125	225
Complementary air	825	1,000	650	800	850	725	625	1,250
Reserve air	350	575	475	825	175	875	550	350
Vital capacity	1,270	1,775	1,225	1,825	1,225	1,775	1,300	1,825
Minute volume	2,100	3,800	2,100	4,000	4,400	3,850	2,500	4,275
O_2 consumption	125	125	150	150	175	175	100	175
Ventilatory equivalent (liters)	1.6	3.0	1.4	2.6	2.5	2.2	2.5	2.4
Ventilatory efficiency (c.c.)	59.5	32.8	71.4	37.5	39.7	45.7	40.0	40.9

An increase of ventilation is noticed on the right side, as was to be expected, not only because of the physiologic increase or right predominance, but also because of the parenchymatous lesions existing in the left lung. This ventilatory predominance of the right side is patent in all the fractions studied. On the other hand, we have to emphasize the fact that the O_2 consumption is

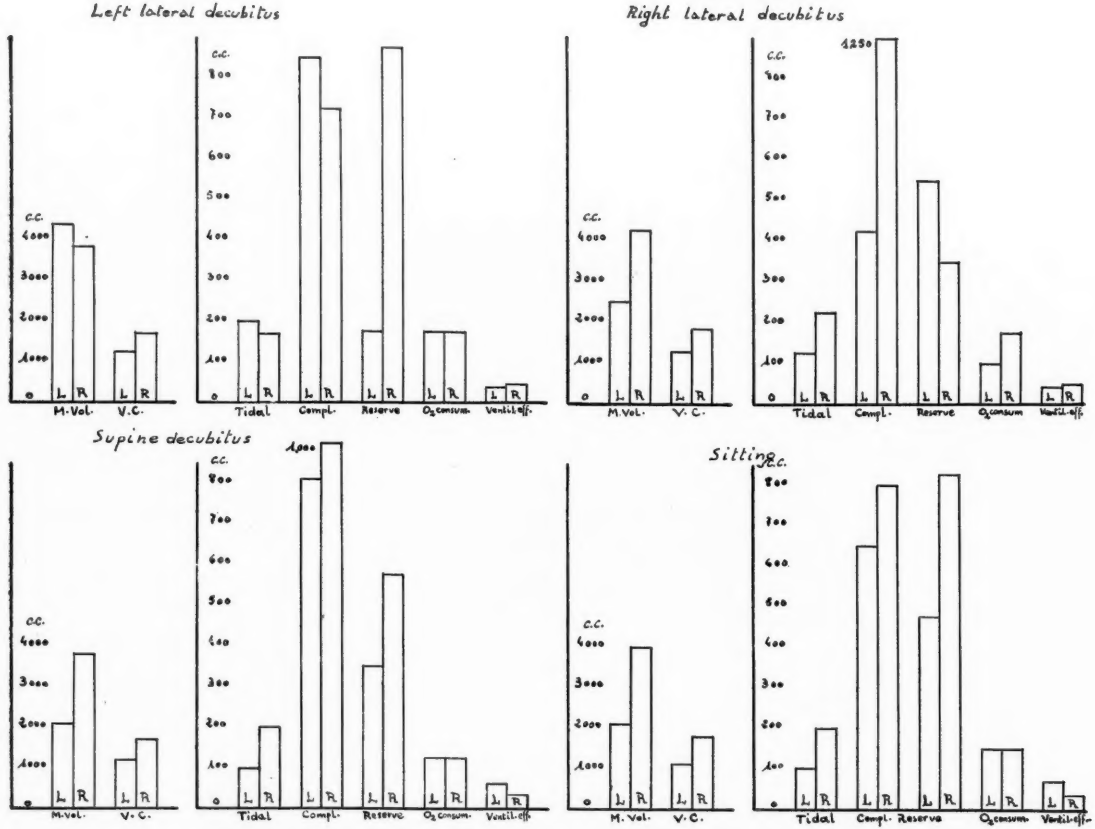

Chart 2.—Absolute values of both sides in the different decubitus positions.

equal in both lungs, so that ventilatory efficiency is greater in the left lung, which is absolutely and relatively less ventilated. We shall return to this presently.

Right Lateral Decubitus.—In this position, approximately the same ratio of tidal air (T.A.) and volume or minute (V.m.) was maintained. There was a decrease in the complementary air in the left lung, both in absolute and in relative value, and an increase in the right lung, both in absolute value and in percentage. The reserve air increased, in absolute value and in percentage, in the left lung and decreased in both ways in the right one.

In regard to respiration, we found an absolute and relative increase of O_2 consumption in the right lung. If in the supine position the proportion for both sides was 50 per cent, respectively, in right lateral decubitus the proportion was 65 per cent on the right side and 35 per cent on the left. The absolute figures in the supine position were 125 c.c. on the left and 125 c.c. on the right; whereas, in right lateral decubitus, the figures were 100 c.c. and 175 c.c., respectively. This demonstrates an important fact which has been pointed out by all the authors who have dealt with this subject, that is, that the ventilatory efficiency (amount of O_2 per liter of ventilated air) has become fundamentally altered, since, whereas in the supine position it was 59.5 c.c. on the left side and 32.8 c.c. on the right, in right decubitus the efficiency dropped to 40 c.c. on the left side and rose to 40.9 c.c. on the right. This means that the left side lost 19.5 c.c. and the right side gained 8.1 c.c., the ratio of one to the other being inverted.

Left Lateral Decubitus.—Here all the values are reversed. The proportion of tidal air increases, absolutely and relatively, in the left lung, since the absolute value of this fraction was 100 c.c. in the supine and 200 c.c. in the left lateral position. The reserve air has considerably decreased in absolute value, having dropped from 350 c.c. in the supine position to 175 c.c. in left lateral, a ratio of left to right becoming established which is 17 per cent and 83 per cent, respectively. The complementary air has slightly increased on the left and dropped considerably on the right; and, as seen in right decubitus, there is an inspiratory situation in the suprajacent lung and an expiratory one for the subjacent lung. The tidal air proportions have hardly changed.

In regard to respiration, we found an equal proportion between the two for O_2 consumption; but, in keeping with the increased ventilation on the left side (V.m., absolutely and relatively increased), the ventilatory efficiency is proportionately lower than on the right side (suprajacent).

Sitting Position.—In this position, the percentage values are practically the same as in supine decubitus and we, therefore, have no special comments to make.

Now, if we make a survey of what we have observed taken as a whole, we arrive at the following conclusions (Chart 2). When a change is made from the supine decubitus position to the right lateral position, an increase of tidal air, proportional on both sides in the case analyzed, is produced. On the

other hand, when a change is made from supine to *left* decubitus, the increase of tidal air produced in the *left* side is much more marked than that in the right side (the figure being doubled), and the same thing applies to the volume per minute. This is explained, in this case, by the existence of the symphysis in the right hemidiaphragm. On the other hand, the ventilatory efficiency decreases in proportion, notwithstanding the fact that the oxygen consumption also increases, the decrease being due to the great increase of tidal air and volume per minute. Yet in right decubitus, in which position the tidal air does not increase, a rise in ventilative efficiency is found, and this is very considerable (from 32.8 c.c. to 45.7 c.c. per liter of ventilated air). This analysis already furnishes a very interesting piece of information, namely, that the increase of ventilation is not parallel to the ventilatory efficiency, although the absolute figures of oxygen consumption rise. This means that the increased ventilation implies the existence of a ventilation which we might call unnecessary ventilation. These findings of ours are not in keeping with those of other authors, but they do tally with what we have found, in a general way, in patients with pulmonary lesions or ones who have been subjected to collapse therapy or space-reducing treatment. In this connection, it is interesting to state that, in the case studied here, as we have already said, it is found that, in the decubitus or the sitting position, the ventilatory efficiency in the left side (the diseased side) is very high (59.5 c.c.) as compared with that on the right side (the healthy one) which is 32.8 c.c. In the former, the volume per minute in supine is 2,100 c.c., whereas in the latter it is 3,800 c.c. We are, therefore, not surprised that when ventilation increases in the left side during left decubitus, there is a drop in ventilatory efficiency.

The complementary air increases systematically in the subjacent hemithorax, which confirms the expiratory situation of the lower hemithorax, in a state of "volumen pulmonum minor," as Björkman said as early as 1934.

The reserve air decreases systematically in the lower hemithorax as a result of its expiratory situation. Unquestionably, as Björkman pointed out, the elevation of the diaphragm is what partly determines the decrease in the volume of the corresponding lung. This also explains the increase in tidal air, as diaphragmatic excursions become easier, although this increase occurs in expiratory position, that is, at a lower tension of the parenchyma. In the upper hemithorax, on the contrary, the reserve air increases very markedly (550 c.c. in the left hemithorax in right decubitus, as against 350 c.c. in supine), and we see that, in left decubitus, the increase of this fraction reaches the figure 875, as against 575 in supine.

The vital capacity increases in the left decubitus position, as do the global volume per minute and oxygen consumption. The increase of vital capacity is due mainly to the considerable increase of complementary air in the lower hemithorax and of the reserve air in the upper hemithorax (see Charts 1 and 2, and Tables I and II).

With regard to the increased oxygen consumption, in absolute values, in lateral decubitus positions, it must be acknowledged that it is related to the

increase of ventilation in absolute terms, and it must be admitted, also, from the observations of others and partly from our own, that the lower hemithorax consumes a larger volume of oxygen. Several authors have attributed this to the afflux of blood to the subjacent lung through congestion due to the action of gravity. This is unquestionable and we shall see a little further on that this is confirmed by x-rays made in lateral positions and in different respiratory phases. But we cannot believe this is the only cause. We shall see further on, from the study of patients, that the reserve air plays an important part in this matter, since there is a rather close connection between the decrease of reserve air and the ventilatory efficiency or proportional oxygen consumption. There must undoubtedly be some other factor and we suspect it may be the ratio of functional residual air, and even of residual air, in the strict sense, to the total lung capacity. We have not been able to get figures for the differential residual air in the two lungs, but the opinion just stated finds support in the roentgenograms, which we shall study next.

However, let us first say that we have observed the greatest changes in left lateral decubitus with a considerable increase of the reserve air in the right lung, and in right decubitus with a complementary considerable increase in the right lung. This is to say that the changes produced by the decubitus position are more noticeable in the right lung, as an expiratory position with a greater reduction of the reserve air and increase of the complementary air in right decubitus, and a greater increase of lung volume in the inspiratory position with an increase of reserve air and decrease of complementary air in left decubitus. Later on, when examining the roentgenograms we shall see that in the left lung the corresponding changes are less marked than in the right lung, which can probably be explained by the presence of the liver below the right hemidiaphragm, joining in the latter's movements as a solid, heavy mass that is more inert.

Radiologic Examination.—Figs. 2 to 11 will demonstrate, better than any explanation could, the changes caused by the lateral decubitus positions.

However, we should like to stress certain essential facts, because they help in understanding some of the changes we have found in the study of bronchospirographic curves.

There is one important fact which we will mention first. It will be a help to explain the last item commented on in the previous paragraph. This is that, in the right lateral decubitus position, the displacement of the right diaphragm during normal breathing reaches 1.2 cm.; whereas, in the left lateral decubitus position, the left hemidiaphragm is displaced as much as 2.95 cm. But a very curious fact is that, whereas, in the left decubitus, the right hemidiaphragm is displaced 3.0 cm., in normal breathing, in right decubitus, the left hemidiaphragm is negatively displaced, that is to say that it paradoxically rises during inspiration.

In the maximal inspiration and maximal expiration positions the displacements of the two hemidiaphragms are as follows: in right decubitus the right side undergoes a displacement of 8.5 cm., whereas in left decubitus the

Fig. 2. Fig. 3.

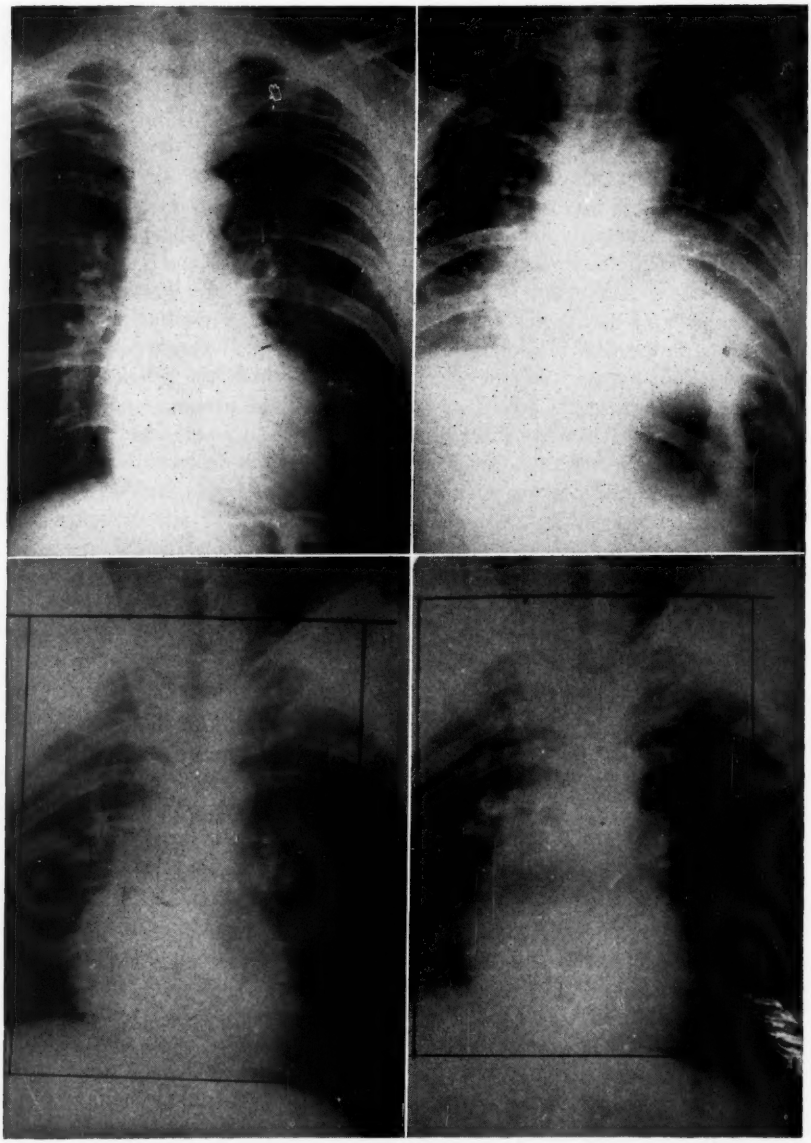

Fig. 4. Fig. 5.

Fig. 2.—Standing. Maximal inspiration.
Fig. 3.—Standing. Maximal expiration.
Fig. 4.—Lateral right decubitus. Normal inspiration.
Fig. 5.—Lateral right decubitus. Normal expiration,

Fig. 6.

Fig. 7.

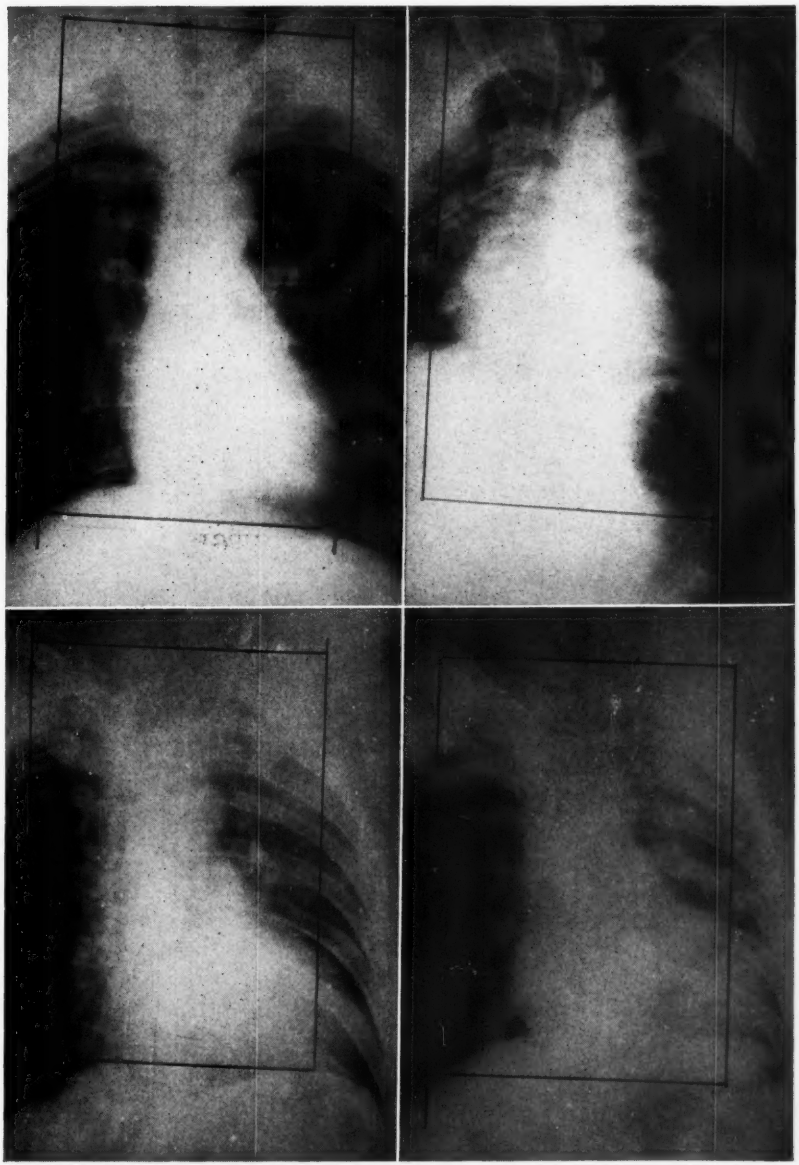

Fig. 8.

Fig. 9.

Fig. 6.—Lateral right decubitus. Maximal inspiration.
Fig. 7.—Lateral right decubitus. Maximal expiration.
Fig. 8.—Lateral left decubitus. Normal inspiration.
Fig. 9.—Lateral left decubitus. Normal expiration.

displacement reaches as much as 10.15 cm. In left decubitus, the left side is displaced 7.2 cm., whereas in right decubitus the displacement only reaches 7.65 cm. This explains the enormous increase of reserve air in the right side during left decubitus and the lesser increase in the left lung in right decubitus.

This brings to an end our comment on the former item. The findings by means of spirography in each side are confirmed by radiology, and the correctness of the method is thus proved.

Fig. 10.

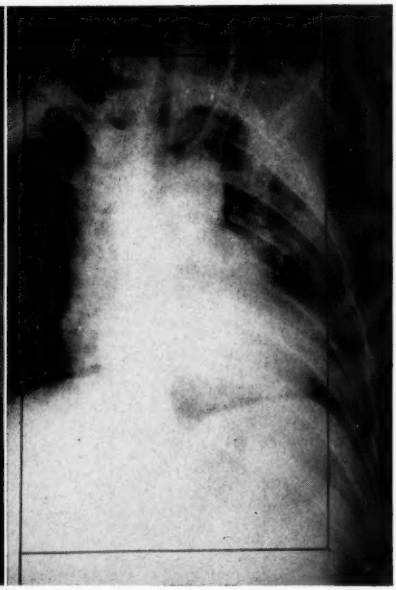

Fig. 11.

Fig. 10.—Lateral left decubitus. Maximal inspiration.
Fig. 11.—Lateral left decubitus. Maximal expiration.

This being ascertained, we have to add that, as seen in the roentgenograms, a tendency to greater obliqueness of the ribs contributes to the lessening of the lung volume on the subjacent side, and this is considerably accentuated in forced expiration. We, thus, understand clearly the decrease of the reserve air and can infer that of the residual air.

Not only are these facts proved, but we can also prove without more ado that the quantity of blood in the subjacent lung is much greater than that in the suprajacent lung, which probably explains this lung's greater capacity for oxygen consumption.

Summing up: Bronchospirometry proves that there is a reduction in the volume of the subjacent lung in the lateral decubitus positions, a greater basal ventilation, an increase of vital capacity, and an increase of oxygen intake in

absolute figures, but a proportional decrease of oxygen absorption or ventilatory efficiency in left decubitus. Radiologic examination explains these findings as far as possible, and adds new data, as, for instance, the increase of the quantity of blood contained in the subjacent lung. If we want to find an explanation for the reduced ventilatory efficiency in the lower lung in left decubitus, we have to believe that the greater ventilation coincides with a decrease of the functional residual air or of the equilibrium level, as a result of which, during the expiratory phase, the alveolar remains of oxygen are rapidly exhausted and, even though, in inspiration, the figure for partial oxygen tension is high, this cannot compensate for the shortage of alveolar reserves for expiration.

However, as we shall see later, this explanation, which may seem satisfactory at first sight, is found not to be altogether true when clinical cases are studied, and the difficulties which arise in this situation are thought-provoking.

CLINICAL STUDIES

We have studied 21 patients who had chronic unilateral lesions or in whom there were bilateral disorders, though slight on one side and markedly greater on the other. We analyzed the ventilation separately in each lung in all the group as a whole, and afterward separated the group in two parts for purposes of analysis: those patients who had been subjected to collapse therapy and those who had not been surgically treated. In the former, the disorders might have been caused by the surgical means employed, whereas, in the latter, they were unquestionably due to the disease itself. Table III sets forth the observations better than any verbal description could.

TABLE III. RELATION OF THE AMOUNT OF VENTILATION TO VENTILATORY EFFICIENCY

	SIDE MORE VENTILATED		SIDE LESS VENTILATED	
CASE	MINUTE VOLUME (C.C.)	VENTILATORY EFFICIENCY (C.C.)	MINUTE VOLUME (C.C.)	VENTILATORY EFFICIENCY (C.C.)
1	8,500	29.4	3,325	60
2	7,200	17	5,400	20.3
3	10,000	10	5,000	40
4	6,400	15.6	3,200	23.4
5	11,000	24.5	3,300	21.3
6	8,320	37	4,940	24
7	8,000	25	6,300	28
8	8,800	28	2,800	35
9	9,900	25	4,400	11
10	5,175	24	4,600	33
11	8,250	33.3	4,500	44.4
12	9,600	18	6,000	16
13	10,000	25	1,875	70
14	11,000	22.7	2,200	45.4
15	6,800	22	5,950	25
16	6,750	30	1,875	40
17	15,600	16	9,100	24.7
18	7,150	27.2	5,500	20.6
19	3,900	32	2,175	45
20	7,200	20	3,000	33
21	6,000	25	2,500	40
Mean	8,359	24.1	4,187	33.7

Ratio of the Amount of Ventilation to the Ventilatory Efficiency in All Cases.—Table III. Generally speaking, it can be seen from this table that there is unquestionably an inverse ratio between ventilation and ventilatory efficiency. The absolute oxygen consumption is generally greater in the more-ventilated side, as it is in decubitus. But it is evident that, with greater ventilation, the utilization of ventilated oxygen becomes proportionately less. This is confirmed by the average figures. For an average volume per minute of 8,359 for the more-ventilated side, there is an efficiency of 24.1 c.c. per liter, as against 33.7 c.c. (a difference of 9.6 c.c.) on the less-ventilated side.

Ratio of the Volume of Vital Capacity to the Ventilatory Efficiency in All the Cases as a Whole.—Table IV. With a view to finding the reason for the inverse ratio between ventilation and efficiency, we began by trying to find out if a relationship existed between *the changes in tidal air and the proportional absorption of* O_2. For the relation between these two factors to be positive we consider it necessary that the difference between the two sides should be equal to, or above 9.6 c.c., the average found in the previous table. In Table IV, the relevant data are given, and it is seen that for a C.V. volume of 1,568 c.c. (the average figure for the side with the higher C.V.) the ventilatory efficiency is 24 c.c., whereas the figure on the side with the lower C.V. is 33.1 c.c. (C.V. 792). This implies a difference of 9.1 c.c. which is less than that found in the general table of total ventilation.

TABLE IV. RELATION OF THE VITAL CAPACITY TO THE VENTILATORY EFFICIENCY

	SIDE WITH MORE VITAL CAPACITY		SIDE WITH LESS VITAL CAPACITY	
CASE	V. C. (C.C.)	VENTILATORY EFFICIENCY (C.C.)	V. C. (C.C.)	VENTILATORY EFFICIENCY (C.C.)
1	1,950	29.4	1,035	60
2	1,550	17	1,150	20.3
3	1,800	10	1,250	40
4	1,300	15.6	425	23.4
5	1,730	24.5	600	21.3
6	2,400	37	900	24
7	1,550	28	1,450	25
8	1,500	28	875	35
9	1,100	25	350	11
10	1,375	24	1,100	33
11	1,200	33.3	925	44.4
12	1,325	18	500	16
13	1,200	25	250	70
14	1,550	22.7	250	45.4
15	2,050	22	1,350	25
16	2,200	30	750	40
17	2,550	16	1,100	24.7
18	1,025	27.2	750	20.6
19	800	32	575	45
20	750	20	300	33
21	2,025	25	750	40
Mean	1,568	24	792	33.1

We, therefore, conclude that there is no definite relation between the changes in C.V. and efficiency, even though there is a coincidence between the drop in C.V. to a certain limit and greater ventilatory efficiency.

Reserve Air.—Table V. The ratio between reserve air and efficiency is such that the figure for efficiency in the side where it is greater is 24.1 c.c., whereas this same figure is 33.7 c.c. on the side with the lesser air reserve. This means that the difference is 9.6 c.c. This figure is higher than that found in the study of the C.V. and is exactly equal to that for total ventilation.

It follows from the above that what is most important is the actual ventilation, that is, the frequency with which the air circulates and, in the second place, the decrease of reserve air. To define the exact magnitude of these changes in comparison with one another, we should have to make many examinations, and we intend to do so. But, in any case, we do not think the problem is capable of simple solution since the inner mechanisms of the process cannot be cleared up until we can settle the ventilation-alveolar perfusion ratios separately for the two sides and make a differential study of the dead space.

For the time being, we want to record that the findings in this examination agree with those of examination in lateral decubitus, and this proves that the inferences drawn do not rest on erroneous data.

TABLE V. RELATION OF THE RESERVE VOLUME TO THE VENTILATORY EFFICIENCY

	SIDE WITH MORE RESERVE AIR		SIDE WITH LESS RESERVE AIR	
CASE	RESERVE AIR (C.C.)	VENTILATORY EFFICIENCY (C.C.)	RESERVE AIR (C.C.)	VENTILATORY EFFICIENCY (C.C.)
1	950	29.4	375	60
2	450	17	350	20.3
3	200	10	200	40
4	350	15.6	0	23.4
5	380	24.5	100	21.3
6	800	37	350	28
7	750	25	250	28
8	100	28	100	35
9	200	25	50	11
10	300	24	100	33
11	400	33.3	225	44.4
12	225	18	50	16
13	300	25	50	70
14	475	22.7	50	45.4
15	550	22	50	25
16	700	30	150	40
17	700	16	150	24.7
18	600	27.2	50	20.6
19	100	32	50	45
20	300	20	75	33
21	825	25	275	40
Mean	460	24.1	145	33.7

Patients Subjected to Collapse Therapy.—The ratios of volume per minute and ventilatory efficiency in this group (Table VI). Here we see that on the collapsed side the volume per minute average is 4,189 c.c. It must be remembered that the average in the less-ventilated side in the total group of cases was 4,187.6 c.c., which implies practical equality. In the side studied here, the ventilatory efficiency figure is 31.5 c.c., whereas in the total group it was 33.7. That is to say that, although the efficiency is greater in the collapsed side than in the opposite one, it is less than in the total group. This difference

increases when we consider the noncollapsed side. In this, the average volume per minute is 7,582 c.c., with an efficiency of 27.3 c.c., as against an average of 8,359 c.c. for the more ventilated side in the total group, in which the efficiency figure was 24.1. That is to say that the difference between the collapsed and the noncollapsed side is 4.2 c.c., which is less than in the total group. And so, although we consider that collapse therapy brings about an increase of ventilatory efficiency, this increase is less than that found in the global group in the less-ventilated side, whereas in the group under consideration here the less-ventilated side is actually the collapsed side.

TABLE VI. RELATION OF THE AMOUNT OF VENTILATION TO THE VENTILATORY EFFICIENCY IN THE PATIENTS WHO UNDERWENT COLLAPSE MEASURES

	IN THE SIDE WITH COLLAPSE		IN THE SIDE WITHOUT COLLAPSE	
CASE	MINUTE VOLUME (C.C.)	VENTILATORY EFFICIENCY (C.C.)	MINUTE VOLUME (C.C.)	VENTILATORY EFFICIENCY (C.C.)
1	3,325	60	8,500	29.4
4	3,200	23.4	6,400	15.6
5	3,300	21.3	11,000	24.5
6	4,940	24	8,320	37
9	4,400	11	9,900	25
11	8,250	33.3	4,500	44.4
14	2,200	45.4	11,000	22.7
15	5,950	25	6,800	22
18	7,150	27.2	5,500	20.6
19	2,175	45	3,900	32
Mean	4,189	31.5	7,582	27.3

If we contrast the behavior of the *vital capacity* (Table VII) with ventilatory efficiency, we find that the figures are exactly equal to those in the group just studied; and we, therefore, do not think it necessary to make any further comment.

TABLE VII. RELATION OF THE VITAL CAPACITY AND THE VENTILATORY EFFICIENCY IN THE PATIENTS WHO UNDERWENT COLLAPSE MEASURES

	IN THE SIDE WITH COLLAPSE		IN THE SIDE WITHOUT COLLAPSE	
CASE	VITAL CAPACITY (C.C.)	VENTILATORY EFFICIENCY (C.C.)	VITAL CAPACITY (C.C.)	VENTILATORY EFFICIENCY (C.C.)
1	1,035	60	1,950	29.4
4	425	23.4	1,300	15.6
5	600	21.3	1,730	24.5
6	900	24	2,400	37
9	350	11	1,100	25
11	1,200	33.3	925	44.4
14	250	45.4	1,550	22.7
15	1,350	25	2,050	22
18	1,025	27.2	750	20.6
19	575	45	800	32
Mean	770	31.5	1,445	27.3

We can say the same about the reserve air, for, as will be seen in Table VIII, the figures are practically equal to those in the former groups.

The most interesting group is that consisting of the patients in whom *no* surgical operation was performed on the thorax. In this group we have analyzed the ventilatory constants exactly in the same way as in the previous ones, and the findings follow.

TABLE VIII. RELATION OF THE RESERVE AIR TO THE VENTILATORY EFFICIENCY IN THE PATIENTS WHO UNDERWENT COLLAPSE MEASURES

	IN THE SIDE WITH COLLAPSE		IN THE SIDE WITHOUT COLLAPSE	
CASE	RESERVE AIR (C.C.)	VENTILATORY EFFICIENCY (C.C.)	RESERVE AIR (C.C.)	VENTILATORY EFFICIENCY (C.C.)
1	375	60	950	29.4
4	0	23.4	350	15.6
5	100	21.3	380	24.5
6	350	24	800	37
9	50	11	200	25
11	400	33.3	225	44.4
14	50	45.4	475	22.7
15	50	25	550	22
18	100	27.2	50	20.6
19	50	45	100	32
Mean	152.5	31.56	408.0	27.3

Ratio of the Amount of Ventilation to Ventilatory Efficiency in Subjects Not Undergoing Collapse Therapy.—Table IX. In this table, the ratio of increased ventilation to decreased efficiency, and vice versa, is clearly seen. Indeed, the average volume per minute is 8,712 c.c. (somewhat higher than in the total group) in the more-ventilated side, with an efficiency of 22.1, as against 35.9 efficiency in the less-ventilated side (volume per minute, 3,705 c.c.). That is to say that there is a difference between the more-ventilated side and the less-ventilated one, in regard to ventilatory efficiency, of 13.8 in favor of the less-ventilated side, when this decrease of ventilation is due to the disease itself. (Not in all cases, for there are some in which, exceptionally, the less-ventilated side was the healthy one; but in one of them, phrenicotomy had been performed some time before and, although the diaphragm function was restored, the diaphragm itself was fixed in a wrong position.)

TABLE IX. RELATION OF THE AMOUNT OF VENTILATION TO THE VENTILATORY EFFICIENCY IN THE PATIENTS WHO DID NOT UNDERGO COLLAPSE MEASURES

	IN THE MORE-VENTILATED SIDE		IN THE LESS-VENTILATED SIDE	
CASE	MINUTE VOLUME (C.C.)	VENTILATORY EFFICIENCY (C.C.)	MINUTE VOLUME (C.C.)	VENTILATORY EFFICIENCY (C.C.)
3	10,000	10	5,000	40
7	8,000	25	6,300	28
8	8,800	28	2,800	35
10	5,175	24	4,600	33
12	9,600	18	6,000	16
13	10,000	25	1,875	70
16	6,750	30	1,875	40
17	15,600	16	3,100	24.7
20	7,200	20	3,000	33
21	6,000	25	2,500	40
Mean	8,712.5	22.1	3,705.0	35.9

The *vital capacity* (Table X) shows a certain relation in the same sense, as is proved by the fact that the side with more capacity had an efficiency of 22.4 c.c. (C.V. 1,627.5) whereas the opposite side had an efficiency of 35.6 c.c. with a C.V. of 832; that is to say that the difference was 13.2 c.c., very similar to what was observed in the study of total ventilation.

TABLE X. RELATION OF THE VITAL CAPACITY TO THE VENTILATORY EFFICIENCY IN THE PATIENTS WHO DID NOT UNDERGO COLLAPSE MEASURES

	IN THE SIDE WITH GREATER V. C.		IN THE SIDE WITH LESS V. C.	
CASE	VITAL CAPACITY (C.C.)	VENTILATORY EFFICIENCY (C.C.)	VITAL CAPACITY (C.C.)	VENTILATORY EFFICIENCY (C.C.)
3	1,800	10	1,250	40
7	1,550	28	1,450	25
8	1,500	28	875	35
10	1,375	24	1,100	33
12	1,325	18	500	16
13	1,200	25	250	70
16	2,200	30	750	40
17	2,550	16	1,100	24.7
20	750	20	300	33
21	2,025	25	750	40
Mean	1,627.5	22.4	832.5	35.6

In regard to the *reserve air,* we found less relationship, as will be seen from Table XI.

If we now make a comparative study of the amount of ventilation in the diseased and in the healthy side, respectively, we find some even more interesting data. Thus, in Table XII, we find certain items which give much food for thought. This table is made up of the data from patients with certain unilateral lesions of various degrees of severity, in some cases reaching total dysfunction of the hemithorax affected with fibrothorax, caseation, etc. The number of cases analyzed was 10. Eight of these are numbered 3, 8, 10, 13, 16, 17, 20, and 21. The other 2, *a* and *b*, are cases not included in the previous analysis since the affected hemithorax was excluded from ventilation in one of them, and, in the other, it only ventilated 1,000 c.c. per minute, with efficiency nil. This led us to analyze, as far as possible, the limits from which ventilatory efficiency rises or drops. (Table XI.)

TABLE XI. RELATION OF THE RESERVE AIR TO THE VENTILATORY EFFICIENCY IN THE PATIENTS WHO DID NOT UNDERGO COLLAPSE MEASURES

	SIDE WITH MORE RESERVE AIR		SIDE WITH LESS RESERVE AIR	
CASE	RESERVE AIR (C.C.)	VENTILATORY EFFICIENCY (C.C.)	RESERVE AIR (C.C.)	VENTILATORY EFFICIENCY (C.C.)
3	200	40	200	10
7	750	25	250	28
8	100	35	100	28
10	300	24	100	33
12	225	18	50	16
13	300	25	50	70
16	700	30	150	40
17	700	16	150	24.7
20	300	20	75	33
21	825	25	275	40
Mean	440	25.8	140	32.2

Of course, we realize that we have only dealt with 10 cases, very few for drawing conclusions, but, we can at least survey the results of their individual tests. On the basis of these data we drew Chart 3 and compiled Table XII.

TABLE XII. RELATION OF THE VENTILATION TO THE VENTILATORY EFFICIENCY IN BOTH SIDES (ILL AND HEALTHY)

CASE	ILL SIDE		HEALTHY SIDE	
	MINUTE VOLUME (C.C.)	VENTILATORY EFFICIENCY (C.C.)	MINUTE VOLUME (C.C.)	VENTILATORY EFFICIENCY (C.C.)
3	5,000	40	10,000	10
8	2,800	35	8,800	28
10*	5,175	24	4,600	33
13	1,875	70	10,000	25
(a)†	0	0	10,080	29
16	1,875	40	6,750	30
(b)†	1,300	0	11,700	39
17	9,100	24.6	15,600	16
20	7,200	20	3,000	33
21	2,500	40	6,000	25

*Phrenectomy on the ill side. Nevertheless, there is more minute volume and less ventilatory efficiency than on the healthy side.

†Cases not included in Tables I through XI.

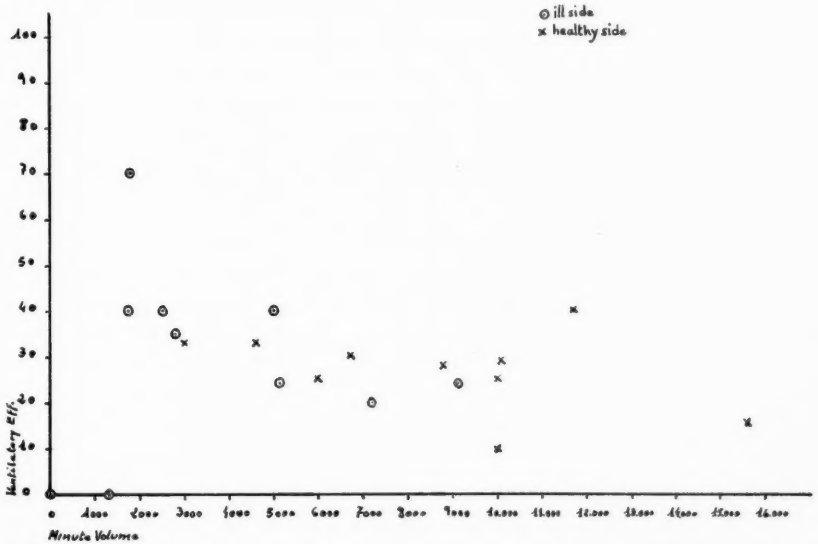

Chart 3.—Relationship of the amount of ventilation to the ventilatory efficiency on both sides (ill and healthy).

If we include the cases in which there was no O_2 consumption in the affected side (there are 2 of these), we find that the average volume per minute in this side was 4,440 c.c., with an average efficiency of 31.7; whereas on the healthy side the volume per minute average was 6,483, with an efficiency of 21, which means that there is a difference of 10.7 c.c. in average efficiency between the healthy side and the diseased one. But it must be stated that, paradoxically, the ventilation was reversed in 2 cases, being greater on the diseased side and,

in both, there was less efficiency than on the less-ventilated healthy side. If we exclude these 2 cases and concentrate on the efficiency in those in which the volume per minute was lower on the affected side, we find (Cases 3, 8, 13, 16, 17, and 21) that the volume per minute average in the diseased side was 3,858 c.c., with an average efficiency of 41.6, as against a volume per minute of 9,525 on the healthy side, and an efficiency of 22.3, so that there is a difference of 19.3 c.c. in efficiency between the diseased side and the healthy one. This is the largest difference we have found in our study of the averages.

If, as we suggested a little while ago, we now try to find the limits from which the variations start by analyzing the frequency diagram (Chart 3) done on the basis of the data in Table XII, we shall see that for volumes per minute below 1,000, the ventilatory efficiency is nil, but that it rapidly rises in the neighborhood of 2,000 c.c., and drops again progressively and rather gradually; or, in other words, that with high volumes per minute the efficiency is low, but the latter rises as the volume drops and falls to nil when the volume is below a certain limit, which, for the time being, we provisionally settle at 1,000 c.c.

DISCUSSION

There unquestionably exists an almost systematically proved fact that, within stated limits (which, for the time being, we cannot accurately define and which are independent of the increased oxygen absorption in each lung in absolute figures), as ventilation increases the utilization of this gas decreases, and by this we mean the proportion in which it is absorbed per liter of ventilated air. This fact is not new, being already known in connection with effort tests, in which it is found that, after a progressive increase of oxygen consumption and volume per minute, a situation is reached, which is internationally known as steady state, in which a debt remains as long as the system of work employed is in action. On the other hand, it is also known that the hyperventilation concurrent with the effort tests is accompanied by an elevation of the ventilatory equivalent. Therefore, our observation is in no way new. But we consider it is so in a certain sense, for it is apparently paradoxical that, in one and the same case, in the diseased side or in the collapsed side, for instance, in which ventilation is lessened by the means used or by the disease itself, this ventilation should occur with greater efficiency. Even in the healthy individual, when we place the respiratory system in asymmetry, as happens in lateral decubitus positions, we find that, independent of the decrease in absolute quantity of the absorbed oxygen, the less-ventilated side sometimes absorbs proportionately more oxygen than the more-ventilated one. Naturally, we cannot assert that the progressive drop in ventilation constantly runs parallel to an increase of efficiency; but there is undoubtedly a limit, which, for the time being, we provisionally set at 1,000 c.c., at which oxygen absorption finally fails.

We cannot attempt a sure explanation of the phenomenon, which is probably to be found in the proportion of "ideal" alveoli, as Cournand understands this term, which exist in the lung in which the capacity is lessened. Perhaps

in this case the proportion of well-ventilated and well-irrigated alveoli may be higher, as a compensating mechanism in view of the loss of effective surface. Perhaps it may be found in the blood diversion mechanism from badly ventilated or nonventilated areas to better ventilated territories, converting all the potential (i.e., nonfunctional) ones into actual ones, from the standpoint of ventilation-irrigation ratios.

The fact is worth attention that ventilatory efficiency reaches its highest level precisely in those cases of ours in which we found a drop in ventilation due to disease, as against those in which therapeutic means had been applied to reduce the functional surface. Is it perhaps that the compensating phenomena are very slow in developing and, therefore, when the disease is the cause of the changes studied, there is more time for the mechanisms to come into play? Another idea which occurs to us is that perhaps the decrease of residual functional air may allow a fuller mixture of inspired air with the alveolar air remaining. But this is not an acceptable explanation, for anoxia would result during expiration.

Perhaps the study of pulmonary vascularization would furnish some accurate information in this connection; but we hardly think so. The study of the roentgenograms in lateral positions shows an evident congestion of the subjacent lung. On the other hand, the already classic studies of Lopo de Carvalho and those of Raul Vaccarezza have proved that in the collapsed parts there is less vascularization. However, we said just now that we did not think these data could be readily used, because the only thing we can say so far, after using angiography, is whether or not there is an increase in the amount of blood, but not what its dynamics are in regard to alveolar capillary circulation.

SUMMARY

Summing up, we consider that there is a large fraction in ventilation which must be looked upon as a "reserve ventilation."

There exist delicate adaptation mechanisms, many of which are perfectly known, whereas others are less known, make it possible to accomplish the arterialization of the blood effectively, even after considerable reduction in the breathing surface. However, this must undoubtedly occur by the conversion of a potential, or reserve, function into an actual one, thus eliminating the reserves in favor of basal respiration.

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ARTERIAL PATTERNS OF RIGHT UPPER LOBE

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INTRODUCTION

IN PREVIOUS publications the arterial supply of the left upper lobe has been discussed in some detail.[1, 2] Since the right upper lobe supply is also highly variable, it may be interesting and helpful to consider some of its patterns.

MATERIAL

Twenty-five dissected adult male lungs were used in this anatomic study. Illustrations not previously depicted[1] are given in Figs. 1 to 15.

DISCUSSION

As is well known, the right pulmonary artery divides into a superior and inferior (interlobar) trunk and usually both trunks supply the upper lobe segments. Boyden and Scannell,[4] in 50 right upper lobes, found that the lobe was supplied exclusively by the superior trunk in only 8 per cent of the specimens. Later, Boyden and Hamre,[3] on the basis of 100 specimens, modified the figure to 18 per cent. In other words, 82 per cent received a dual supply: from the upper and lower trunks of the right pulmonary artery. My own data showed that in 96 per cent, an artery to the posterior segment arose from the inferior trunk and in 36 per cent an artery to both the anterior and posterior segments arose from the inferior trunk. In both instances they arose in the vicinity of origin of a middle lobe artery.

Boyden and Scannell[4] found the prevailing pattern of the superior trunk to be a bifurcation in 68 per cent and a trifurcation in 18 per cent. In the case of a bifurcate type of superior trunk, the upper division gave off branches chiefly to the apical and posterior segments; the lower division supplied chiefly the anterior segment. In instances where the upper trunk of right pulmonary artery was trifurcate, an artery for the posterior segment arose from the middle limb in over one-half the specimens.

In my dissections, the pattern of the superior trunk was bifurcate in 72 per cent, trifurcate in 24 per cent, and quadruplate in 4 per cent. A true (direct) branch to the posterior segment arose from the superior trunk in 20 per cent; in 16 per cent it was one branch of a trifurcate pattern and in 4 per cent was one branch of a quadruplate pattern.

The opinions expressed are those of the author and do not necessarily reflect those of the Veterans Administration.

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Multiple Arterial Supply to Anterior Segment.—The anterior segment artery or arteries arise from the superior trunk in a highly variable manner. An additional supply to the anterior segment arises from the inferior (interlobar) trunk in a high percentage. The level of origin of these accessory vessels and their relation to the anterior segment bronchus is also variable. Boyden and Scannell have considered the superior trunk of the right pulmonary artery as the "truncus anticus superior" from which, of course, branches to all three upper lobe segments can arise. The additional arterial supply to the anterior segment arising from the inferior trunk of the right pulmonary artery was called a "truncus anticus inferior," if it coursed anterior to the anterior segment bronchus (14 per cent), and "anterior ascending," if it coursed posterior to this bronchus (40 per cent). My own figures show an ascending artery to the anterior segment in 36 per cent of the specimens. In my interpretation of the anatomic data, there was a third or intermediate level of origin of an artery to the anterior segment (Fig. 8). I have called this artery a "truncus anticus intermedius," rather than a "truncus anticus inferior," to emphasize that it is not necessarily the most inferior or caudad branch to the anterior segment since, in a greater percentage, an artery for this segment arises more caudally from the inferior trunk. Indeed, the anterior segment may be served by arteries arising at three levels. The anatomic names assigned are not too important. The important point is to recognize anterior segment arteries arising from all possible levels.

Multiple Arterial Supply to Posterior Segment.—Boyden and Scannell have classified the arterial supply of the posterior segment into two main types. It can be stated as follows: An arterial branch to the posterior segment is designated "recurrent" if it courses *anterior* to the anterior segment bronchus, regardless of whether it arises from the superior or inferior trunk of the right pulmonary artery. An arterial branch for the posterior segment which arises from the inferior trunk of the right pulmonary artery is called "posterior ascending" if it courses *posterior* to the anterior segment bronchus.

Boyden and Hamre,[3] on the basis of 100 specimens, found an "ascending" artery to the posterior segment in 82 per cent. In my much smaller series, I found an inferior trunk origin of an ascending artery to the posterior segment in 96 per cent. The posterior segment was supplied *exclusively* by an ascending artery from the inferior trunk in only 16 per cent of instances.

Level of Origin of Ascending Arteries in Relation to Middle and Lower Lobe Arteries.—Due to the close point of origin of these arteries, a free intermediate artery, proximal to the origin of middle and lower lobe arteries, was present in less than 50 per cent (Boyden and Hamre) and in only 12 per cent in my anatomic series (Figs. 2 and 8). In Lindskog, Liebow, and Hales series,[5] an intermediate artery was absent in only 24 per cent and was less than 5 mm. in length in 12 per cent. Boyden and Hamre found the origins of ascending arteries to the upper lobe to be *caudad* to a middle lobe artery in 12 per cent; *at the level of* a middle lobe artery in 40 per cent cent. Ascending arteries to the upper lobe

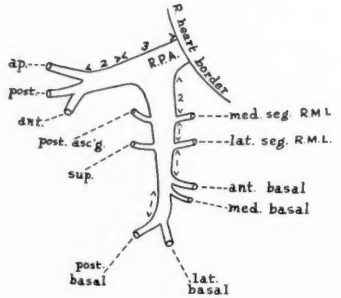
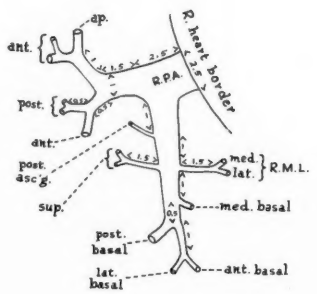


Fig. 1.



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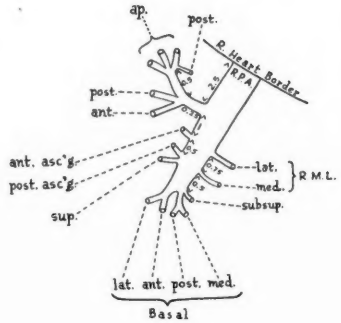


Fig. 3.

Fig. 1.—Upper trunk of right pulmonary artery is bifurcate, with the lower division of the bifurcation giving an important branch to the posterior segment. Numerals represent centimeters.

Fig. 2.—Upper trunk is bifurcate. Upper division gives important branch to anterior segment. Lower division gives important branch to posterior segment.

Fig. 3.—Upper trunk is trifurcate and gives an important branch to the posterior segment.

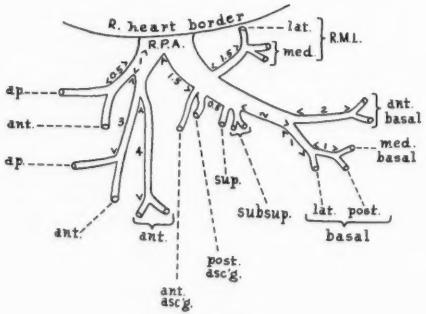
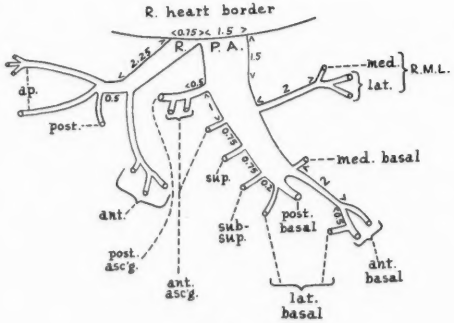


Fig. 4.



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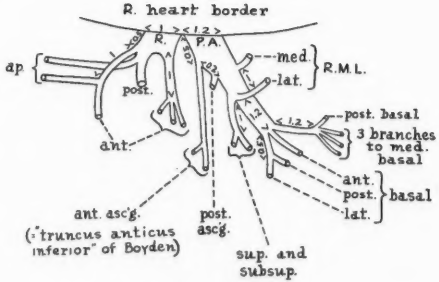
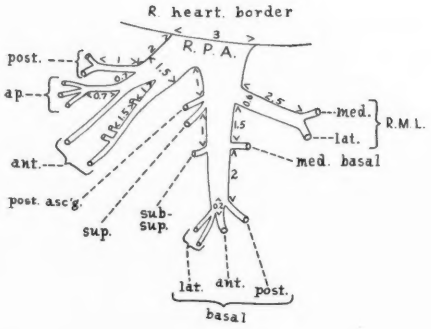


Fig. 6.

Fig. 4.—Upper trunk is bifurcate. Upper division gives a major branch to the anterior segment. Lower division gives an important branch to the apical segment. Posterior segment is supplied exclusively by an "ascending" artery from the inferior trunk.

Fig. 5.—Upper trunk is a bifurcation whose upper division is itself a trifurcate pattern which gives off a posterior segment branch. Ascending arteries to both anterior and posterior segments arise by a common stem from the inferior trunk.

Fig. 6.—Upper trunk is a bifurcation whose upper division gives an important branch to the apical, anterior, and posterior segments.



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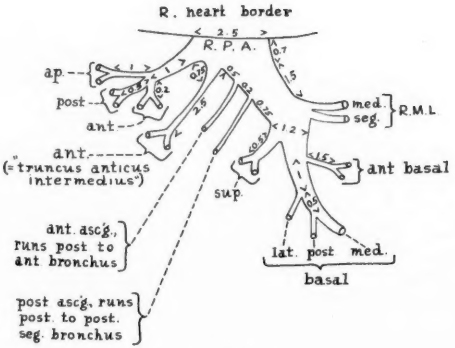

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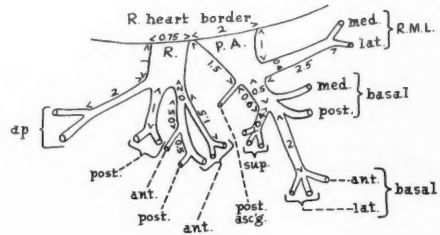


Fig. 9.

Fig. 7.—Upper trunk is a bifurcation whose upper division gives an important branch to posterior segment.

Fig. 8.—Upper trunk trifurcates into almost equal branches for all three upper lobe segments. The anterior segment is also supplied by an artery arising in an intermediate position and by still another artery—the anterior ascending.

Fig. 9.—Upper trunk is a trifurcation with the middle branch for the posterior segment.

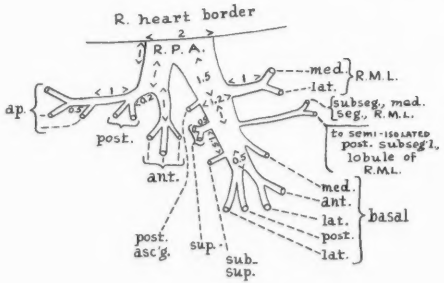
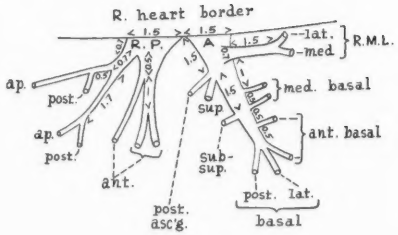


Fig. 10.



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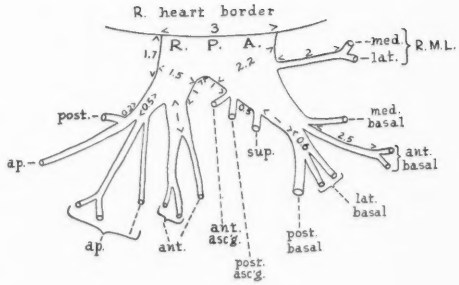
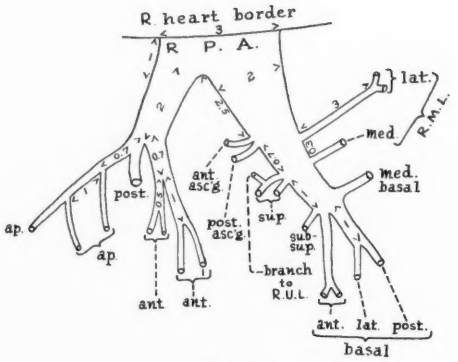


Fig. 12.

Fig. 10.—Upper trunk is a bifurcation whose upper division trifurcates. Lower two branches of this trifurcation are for the posterior segment.

Fig. 11.—Superior trunk is a bifurcation whose upper division bifurcates twice to give posterior segment branches which are just as important as the apical branches. Ascending artery to the posterior segment arises from a common stem with the superior segment artery.

Fig. 12.—Anterior and posterior ascending arteries arise from a common stem. The posterior segment is also supplied by a "recurrent" branch from the apical artery.



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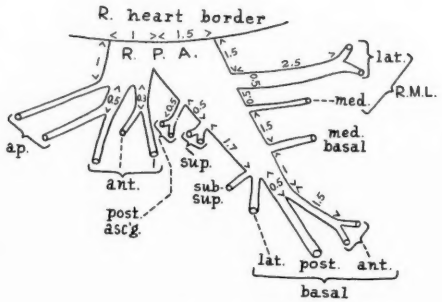

Fig. 14.

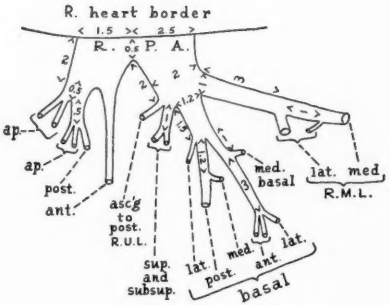

Fig. 15.

Fig. 13.—Upper division of the superior trunk gives an important branch to the posterior segment. Ascending arteries to anterior and posterior segments arise from virtually a common stem. A branch from the superior segment artery supplies the upper lobe.

Fig. 14.—Posterior segment is served exclusively by an ascending artery from the inferior trunk.

Fig. 15.—Posterior segment is supplied by a "recurrent" branch from the apical artery and an ascending artery from the inferior trunk.

arose from the superior segment artery of the lower lobe in 6 per cent and from a middle lobe artery in 4 per cent. These factors are of importance not only in upper lobe surgery but also in middle and lower lobe surgery.

The intermediate artery does not usually lend itself to just one ligation which would suffice in bilobectomy of the middle and lower lobes. On the other hand, the intermediate *bronchus,* from which stem the origins of the middle and lower lobe bronchi, is usually adequate in length for section and suture in bilobectomy; one to 2.5 cm.[1]

SUMMARY

The impression is sometimes gained in descriptions of surgical anatomy, that the arterial patterns of the right upper lobe have been presented in insufficient detail. According to these oversimplified versions, the upper trunk of the right pulmonary artery has chiefly an apical and anterior branch which may give off relatively small and unimportant "recurrent" branches to the posterior segment; the lower or interlobar pulmonary trunk gives off chiefly an "ascending" branch which is the main arterial supply to the posterior segment.

Such a concept is contrary to anatomic studies and is fraught with potential danger to the blood supply of the segments. I have found, in 20 per cent of specimens, that a true hilar branch of the upper trunk of the right pulmonary artery supplied the posterior segment. In an additional 36 per cent, the posterior segment was supplied in a more complex way by a major arterial component of a bifurcate, trifurcate, or other pattern of the upper trunk of the pulmonary artery. In other words, in 56 per cent, the hilar arteries of the upper trunk which supplied the posterior segment were *important vessels,* not merely relatively minor "recurrent" branches.

Moreover, the inferior (interlobar) trunk gave "ascending" branches to the posterior or anterior segments; these arose, at about the level of a middle lobe artery, in approximately 95 and 35 per cent, respectively. In an additional 12 per cent, an artery for the anterior segment arose from a position intermediate between the origin of the "ascending" arteries and the superior hilar level.

From a consideration of the above factors, it is clear that the right upper lobe can vie with the left upper lobe so far as complexity of arterial supply is concerned. So varied are the arterial patterns that each situation demands highly individualized surgical management.

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RUPTURE-SEPARATION OF THE CERVICAL TRACHEA FOLLOWING A CLOSED CHEST INJURY

Report of a Case Successfully Treated by Primary Anastomosis

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Baton Rouge, La.

THE increasing severity of automobile accidents has made rupture or tear of the tracheobronchial tree a not uncommon complication of thoracic trauma. The recent demonstrations of successful primary closure or anastomosis in such cases have made the early recognition of tracheobronchial disruption of paramount importance.

Rupture or tear of the cervical trachea alone, secondary to closed trauma to the chest, is an extremely rare complication. I could not find any recent reports of complete traumatic rupture of the cervical trachea from such closed injury. However, there are scattered reports of apparent posttraumatic tracheal stricture, presumably due to earlier and unrecognized tracheal tears. The prompt recognition of this serious complication following chest trauma can lead to immediate restoration of tracheal continuity by anastomosis, and can prevent the delayed morbidity, should the patient survive the initial insult.

Because of the rarity of this complication, and in order to present the attendant clinical features, a case of complete rupture and separation of the cervical trachea following a "steering-post" injury of the chest is presented.

CASE REPORT

C. B., a 40-year-old white man, was admitted to the Emergency Room of the Baton Rouge General Hospital on Nov. 29, 1955, within twenty minutes of his involvement in a head-on automobile collision. The initial examination revealed the patient to be moderately cyanotic and tachypneic, with a rapid feeble pulse of 120 and no obtainable blood pressure. There were scattered superficial abrasions over the scalp, face, and right shoulder. There was marked subcutaneous emphysema of the upper right thoracic wall, neck, and face. There was a clinically evident fracture of the anterior right first and second ribs. There was also an evident fracture-dislocation of the right hip. The patient's blood pressure was restored by the immediate transfusion of two units of whole blood. Further physical examination and x-ray of the chest revealed a 30 per cent pneumothorax of the right pleural cavity. A closed tube drainage was established on the right side, with no relief of the patient's severe respiratory distress.

Because of the marked emphysema of the neck and because the cervical emphysema was far out of proportion to the rather minimal right pneumothorax, it was thought that the patient might have sustained a bronchial tear (Fig. 1). An emergency tracheotomy was attempted through the standard low midline collar incision, and it was immediately noted that the trachea was absent in the region of the suprasternal notch. The neck incision was enlarged and a huge tension air-dissection of the deep cervical fascia was observed. Upon release of this tension, there was momentary improvement in the patient's moribund

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condition. Further examination revealed a complete fracture-separation of the trachea, with retraction of the lower cervical trachea deep into the superior mediastinum. The upper fragmented portion of the trachea was retracted cephalad. Both ends of the trachea were located by digital palpation, grasped with several Allis forceps and brought into visibility. Soon after suction of the aspirated blood from the distal tracheal segment, the patient's color was dramatically improved, as was his general over-all condition. It was observed that there was a clean anterior fracture-separation between two of the cartilages just below the larynx, and a ragged separation of the posterior membranous wall of the trachea (Fig. 2).

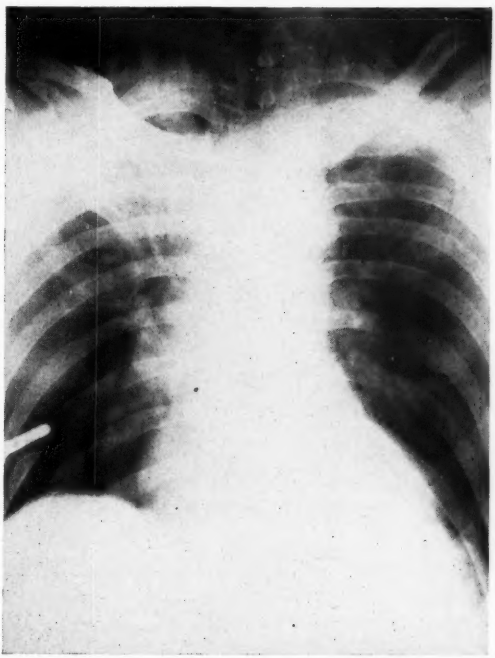

Fig. 1.—Upright portable chest film taken soon after admission and before surgical correction of tracheal separation. The extensive localized cervical emphysema can be seen.

The patient was taken to the operating room, and under local anesthesia, the ragged edges of the separated ends of the trachea were smoothed and tracheal continuity established circumferentially by a layer of interrupted everting sutures of fine stainless steel wire. A tracheostomy was established below the line of anastomosis and brought out through the central portion of the wound just above the suprasternal notch. The superior mediastinum was drained by Penrose drains bilaterally, and the wound loosely approximated.

The right pneumothorax cleared within twenty-four hours with excellent re-expansion of the right lung. The drainage tube was removed. Four days later, the patient's respiratory status was considered to be completely satisfactory. At that time he underwent an open reduction of the fracture-dislocation of his right hip. The tracheotomy tube was removed on the tenth postoperative day. On the fourteenth day, a localized incision-and-drainage was carried out in the region of the tracheal anastomosis in order to evacuate a small collection of pus. The wound healed completely within nineteen days.

To date, the patient has had no further difficulty and there has been no evidence of stricture formation or suppuration at the line of anastomosis.

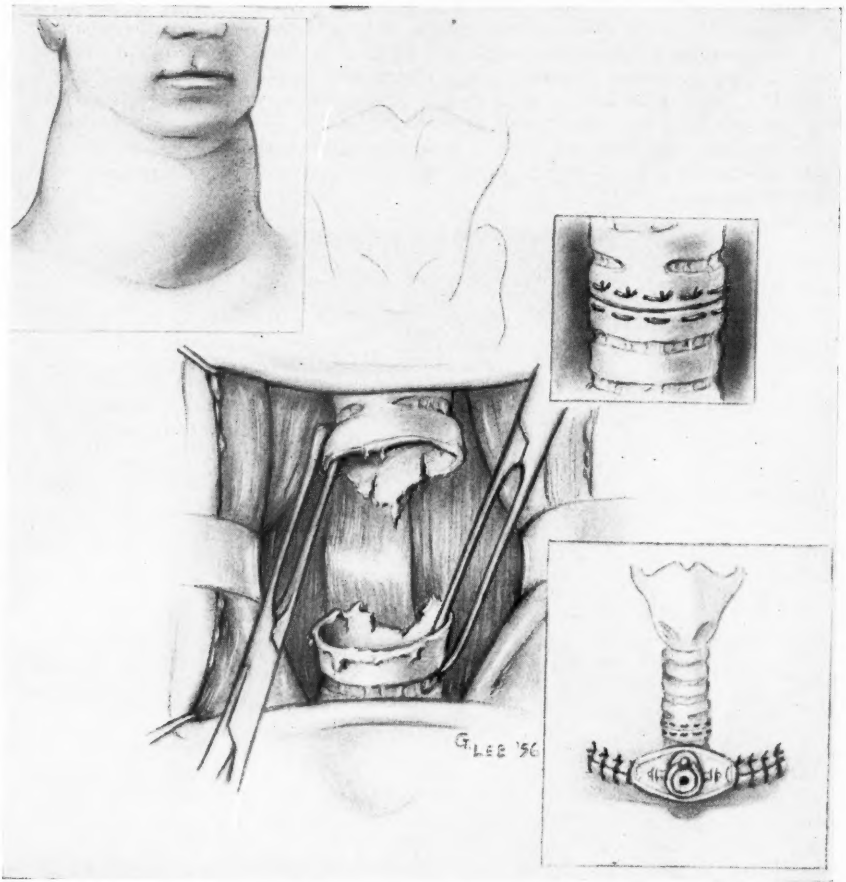

Fig. 2.—Drawing illustrating rupture-separation of cervical trachea, as described, and steps taken in establishing tracheal continuity.

SUMMARY

A case of complete traumatic rupture of the cervical trachea following a "steering-post" injury of the chest is presented.

The rarity of this complication of chest injuries is probably due to the fact that most patients do not survive the initial insult of cervical tracheal separation.

The presence of marked cervical subcutaneous emphysema associated with a closed injury of the chest should lead to suspicion of this possible complication.

Prompt recognition and restoration of tracheal continuity by anastomosis is paramount.

A case successfully treated by primary anastomosis and distal tracheostomy is described.

COEXISTENT ACHALASIA OF THE ESOPHAGUS AND HIATAL HERNIA OF THE CARDIAC END OF THE STOMACH

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SINCE achalasia of the cardia and hiatal hernia of the stomach are distinct entities of unrelated etiology, their coexistence in an individual is attributable to chance coincidence. According to MacMillan,[5] "cardiospasm" was found in about 0.05 per cent of all admissions to a large general hospital. Feldman[3] estimates the incidence of hiatal hernia to be about one per cent. The cross-incidence, therefore, may be expected to be about 0.005 per cent, or one in 200,000.

Harrington[4] has observed a number of instances of this rare combination at the Mayo Clinic. The roentgenogram of one of these cases was the first to appear in the American literature, in a paper on "Cardiospasm," by Olsen, Holman, and Anderson,[6] in 1953. A second example has very recently appeared in an article on the same subject by Palmer.[7] These authors point out that this coincidence discredits the old theory that a tight or spastic pinchcock action of the diaphragm is the cause of "cardiospasm." Barrier and Lataix,[2] in a discussion of the Heller operation, describe a case, but the radiograph is not reproduced. The only other reference to this coincidence is a statement by Feldman[3] that cardiospasm does not often occur with hiatus hernia. He does not elaborate.

The purpose of this paper is to place a third example of the simultaneous occurrence of achalasia and hiatal hernia on record, and, because both lesions contributed to the production of symptoms, to discuss the diagnostic and thoracic surgical problems posed.

CASE REPORT

Mrs. L. K., a 47-year-old white married woman, was admitted to Onondaga General Hospital, March 3, 1956, with a clinical diagnosis of pneumonia. She had complained of productive cough, fever, and malaise during the preceding three weeks. Her physician had found physical signs of pneumonia at both lung bases and had administered antibiotics. Her fever promptly subsided, but the cough and malaise persisted.

Plain films of the chest showed what appeared to be two oval masses in the posterior mediastinum, one above the level of the arch of the aorta, the other just above the diaphragm, which were inseparable from the aortic and other vascular shadows. There was no demonstrable fluid level. The pulmonary fields were clear.

Fluoroscopic and further radiographic examination, including a barium swallow, revealed a tremendously dilated and tortuous esophagus. In spite of lavage, a considerable

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amount of retained solid material was present. Just above the diaphragm, the alimentary tube was kinked to the left and contained a rather large air bubble (Fig. 1). Identification of the segment was not positive, but because it appeared to have mucous membrane folds more consistent with gastric rugae than with esophageal mucosa, it was considered to be the herniated cardiac portion of the stomach.

In spite of the marked esophagectasis, the contrast agent passed quite rapidly into the portion of the stomach below the diaphragm. The beaked contour characteristic of achalasia was not recognized. Because of this, it was felt that the dilatation was a manifestation of prolonged but intermittent spasm of the juxtagastric portion of the esophagus, secondary to an incarcerated hiatus hernia.

The recent history of pneumonia was attributed to aspiration of overflow from the esophagus, no longer radiographically demonstrable.

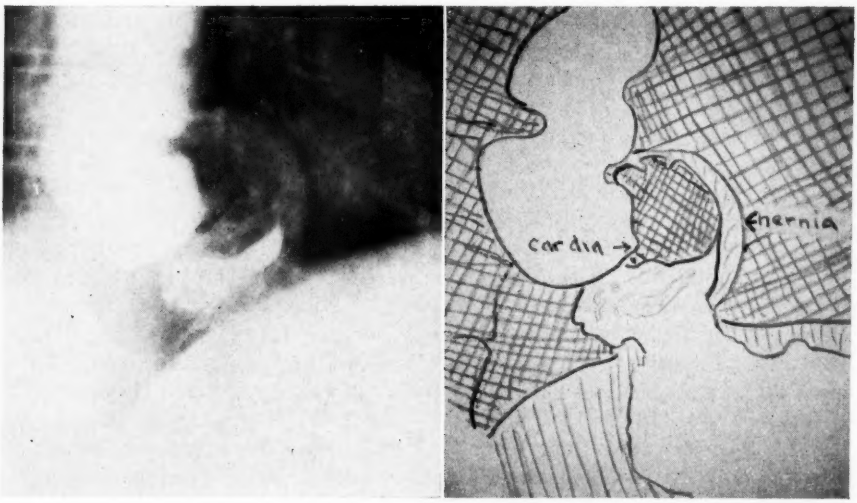

Fig. 1.—Spot film of the cardioesophageal junction (left), and diagrammatic tracing indicating interpretation of findings (right).

On March 10, 1956, the patient was transferred to Crouse-Irving Hospital for further study and treatment. Additional questioning disclosed a ten-year history of dysphagia. During the past two years she had limited her diet to soft foods. Nocturnal cough had become progressively more troublesome during the past six months.

Physical examination was entirely negative except for rather marked obesity, the patient weighing 226 pounds.

Esophagoscopy, March 12, 1956, revealed a markedly dilated and tortuous esophagus. Moderate inflammation of the mucosa with edema was present for an inch or two proximal to the cardia. At 48 cm., an obstruction was encountered preventing complete passage of the instrument. No evidence of scarring or tumor was present. The difficulty in passing this area was attributed to kinking of the elongated esophagus. Esophagoscopic bouginage was then accomplished.

Following dilation, the patient's symptoms improved temporarily, but returned within a few weeks, at which time she became totally obstructed, requiring parenteral fluids. Esophagoscopy was repeated on April 27, 1956, with no change in the endoscopic findings. At this time, endoscopic bouginage could not be accomplished.

At thoracotomy, May 5, 1956, a markedly dilated and boggy esophagus was found. The distal 6 cm. was narrowed and thickened. In addition, a large sliding type of hiatal hernia was present. The region of the esophagogastric junction was sharply angulated. A Heller esophagomyotomy plus reduction and repair of the hiatal hernia were accomplished.

Postoperatively, the patient began eating a soft diet on the fifth day. Improvement continued. During the next four months she returned to a practically normal diet. However, large boluses of poorly masticated food would produce some dysphagia.

DISCUSSION

Diagnosis.—Palmer[7] points out that it is necessary to exclude the possibility that megaesophagus is due to stricture secondary to an esophageal hernia. Barraya and associates[1] have published reproductions of roentgenograms of 2 such cases. Any condition producing partial obstruction of the esophagus, acting over a sufficient period of time, may result in esophagectasis. In addition to achalasia of the cardia, intrinsic or extrinsic tumors, edema or spasm secondary to active inflammation, or postinflammatory cicatrization may constitute the obstructing agents. It is not inconceivable that more than one of these factors may be present in a single individual and that each may contribute to the obstruction. Therefore, it is a matter of some importance to attempt to recognize contributing conditions as well as the most obvious cause of esophagectasis.

In the case presented here, the demonstration of what appeared to be a fairly large hiatal hernia in addition to marked dilatation of the esophagus posed a problem in differential diagnosis. Four possibilities were considered: (1) the hiatal hernia might have produced obstruction and secondary stenosis at the cardia, due to reflux esophagitis, (2) the hernia might have been an incidental occurrence in the presence of achalasia, (3) the hernia might have aggravated an obstruction due primarily to achalasia (as eventually proved to be the case), or (4) the findings attributed to hiatal hernia might have been produced by a pocket of air in a redundant distal segment of elongated and dilated esophagus. Convinced that gastric rugae were present, falsely reassured by the rapid passage of contrast agent into the subdiaphragmatic portion of the stomach, and skeptical of the likelihood of the simultaneous occurrence of both lesions in question, the radiologist made a diagnosis in accordance with the first of the possibilities enumerated, placing it in the same category as the 2 cases reported by Barraya and his associates.[1]

Treatment.—It is apparent from reviewing this case that both factors were responsible for the dysphagia: achalasia with a hypertrophied distal esophageal segment, and angulation at the cardia due to hiatal hernia. Harrington[4] does not advise correction of the hernia when it coexists with achalasia. But in this instance, it was apparent at operation that the angulation present was significant, since it was only relieved with reduction of the hernia. The latter, therefore, was obviously contributing to the obstruction. For this reason, as in the case of Barrier and Lataix,[2] it was decided that, in addition to the Heller procedure, hernial repair was necessary.

SUMMARY

1. Although achalasia of the cardia and hiatal hernia of the stomach are individually not uncommon, their coexistence is rare.

2. A case in which both of these lesions contributed to esophageal obstruction is described. The diagnostic and thoracic surgical problems posed are discussed.

3. Hernial repair, in addition to the Heller operation, appears to be indicated in instances where the hernia constitutes an additional obstructing factor.

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SPONTANEOUS CHYLOTHORAX WITH A BRONCHOPLEURAL FISTULA

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BEFORE Lampson's[1] successful transthoracic ligation of the thoracic duct with subsequent cure of a traumatic chylothorax, a patient with chylothorax presented a most serious problem from the standpoint of management and ultimate prognosis. In 1945, Florer and Ochsner[2] described a 50 per cent mortality for those patients treated by nonsurgical means, and a 100 per cent operative mortality in attempted surgical repair of the duct in a series of 59 cases reported up to 1945. The statements of Andrews,[3] in 1929, that, ". . . surgery (of the thoracic duct) is highly impractical," and of Lillie,[4] in 1935, that, ". . . ligation (of the thoracic duct) in the mid-thorax is almost certainly lethal," convey the general defeatism with regard to this problem. Lampson's successful thoracic duct ligation, followed by successful operations performed by other surgeons, resulted in rendering the surgical treatment of chylothorax a relatively safe and efficacious method. The prognosis, if serious underlying disease is not an etiological factor, is now uniformly good. The purpose of this paper is to present an unusual case of a spontaneous chylothorax with clinical manifestations of a bronchopleural fistula successfully treated by transthoracic ligation of the thoracic duct after attempts to control the disease by tube drainage and supportive measures had failed.

CASE REPORT

A 53-year-old Italian woman was first admitted to Maimonides Hospital on May 7, 1956, with a chief complaint of shortness of breath and cough of five weeks' duration. The patient stated that for many years she had had "bronchitis" characterized by a cough productive of small amounts of yellowish and grayish sputum. Associated with the cough, she had noted occasional wheezing. She had smoked ten to twelve cigarettes a day for the past thirty years. There was no change in her condition until approximately one month prior to admission. At this time, she was awakened from her sleep by an attack of coughing which left her gasping for breath. The sputum, which was whitish with some milky, curdlike material in it, measured approximately one half a cup. From that time up to one week prior to admission, she had noted a continuation of this productive cough with sputum amounting to half a cupful a day which was clear, with occasional chunks of curdlike material, often faintly pink in color. Associated with the increased cough, the patient became aware of orthopnea and increased dyspnea on exertion. Because of these symptoms the patient had a chest film taken at the Board of Health and a report of "wet pleurisy" was made. On admission to the hospital the cough was considerably decreased although dyspnea was pronounced.

The past history and review of systems were essentially noncontributory except for the presence of vague epigastric postprandial distress, and some constipation during the past few years.

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On physical examination the patient was an obese, somewhat dyspneic middle-aged woman, appearing her stated age. There was slight cyanosis present. The temperature was 100° F., rectally, the blood pressure was 170/90 mm. Hg, pulse 90, and respirations 22 per minute. No cervical adenopathy was noted. Small shotty nodes measuring about 0.5 cm. in diameter were palpable in both axillae. Positive physical findings were limited to the chest where marked dullness, decreased breath sounds and decreased fremitus were noted on the right side, extending over the lower two thirds of the chest posteriorly and over the lower one half anteriorly. There were some medium scattered râles heard in the right chest above the area of dullness and basilar crepitant râles throughout the left chest. Examination of the abdomen disclosed a liver edge five fingerbreadths below the costal margin, and a barely palpable spleen.

Admission laboratory data revealed that the urine was yellow, acid, negative for protein, sugar, and acetone and with a specific gravity of 1.022. Microscopic examination of the urine disclosed occasional white blood cells. The hemoglobin was 11.5 Gm. per 100 ml., the white cell count was 6,850 with 71 per cent segmented cells, 11 per cent stab cells, 15 per cent lymphocytes, 1 per cent monocytes, and 1 per cent basophils. The sedimentation rate, the bleeding and clotting times, and the platelet count were all within normal limits. A guaiac test on the stool was negative on several occasions. Blood chemical studies revealed the blood urea nitrogen to be 12, fasting blood sugar 84 mg. per cent, total protein 5.8 Gm. with albumin 3.2 Gm. per cent and globulin 2.6 Gm. per cent. The prothrombin time was normal, as were the cephalin flocculation, thymol turbidity, icterus index, cholesterol and cholesterol esters determinations and the Bromsulphalein test. A chest film taken on admission showed a pleural effusion on the right extending up to the fifth rib posteriorly.

Shortly after admission to the hospital, a thoracentesis was done through the ninth interspace in the mid-scapular line on the right and yielded 1,500 c.c. of milky fluid which did not clot. A Sudan III stain for fat was negative. Cultures for acid-fast bacteria and pathogens were reported to be negative. Fourteen thoracenteses were performed subsequently with a total removal of 11,700 c.c. of chylous fluid. Lymphocyte counts on the fluid ranged from 436 to 1,850. A total protein determination was 4.0 Gm. per cent with 2.6 Gm. per cent albumin and 1.4 Gm. per cent globulin. The total fat was 2 Gm. per cent and the total phospholipids was 258 mg. per cent.

Because of the rapid reaccumulation of fluid, a small polyethylene catheter was inserted into the right chest on May 21, 1956, and the chyle was drained continuously. On May 24, 1956, the patient was fed one-quarter pound of butter containing one gram of D. and C. (drug and cosmetic) green dye No. 6. Twelve hours later the fluid from the chest had a distinct blue-green color, presenting conclusive evidence of a continuing leakage of chyle. A liver biopsy, pleural needle biopsy, examination of pleural fluid for cells, intravenous pyelogram, a gastrointestinal series, sigmoidoscopy, barium enema, and overexposed chest films were negative.

The patient was given a high protein, high carbohydrate, low fat diet. There were no signs of abatement of leakage of chylous fluid after one month of therapy. Accordingly, on June 8, 1956, thoracotomy and ligation of the thoracic duct were performed. As a preliminary measure, a Levine tube was passed four hours before the operative procedure and a mixture of 50 c.c. of olive oil, 50 c.c. of cream and one gram of D. and C. green dye No. 6 were injected via the tube into the stomach. A right posterolateral thoracotomy incision was made with the patient in the lateral position. The eighth rib was resected subperiostially and the pleural cavity entered. Approximately 1,500 c.c. of chyle was evacuated. A relatively thin peel measuring 2 mm. in thickness embraced the diaphragmatic and lateral aspects of the right lower lobe. Upon evacuation of the chyle, the mediastinal pleura and particularly the pulmonary ligament were found to be markedly thickened, but palpation within the right pleural cavity revealed no pathology. No point of leakage of chyle could be seen. The mediastinal pleura was opened just above the diaphragm and the thoracic duct was dissected free in the tissues between the aorta and azygous vein. In order to help delineate the thoracic duct, 25 mg. of Evans Blue dye was injected subcutaneously in the thigh. An accidental nicking of the thoracic duct

during the dissection with subsequent copious drainage of chyle led to the prompt identification of the duct. The latter was dissected for a short distance proximally and distally and ligated with two No. 2-0 silk ties. A fine polyethylene catheter was inserted into the cephalad portion of the thoracic duct and sterile saline injected, but no point of leakage could be identified. The duct was ligated above with a No. 2-0 silk tie. It was now noted that the duct caudad to the ties was markedly dilated and tense with slight seepage of chyle around the lowest silk tie. Accordingly, the duct was religated with umbilical tape caudad to the silk ties, resulting in complete cessation of chyle leakage. Accessory ducts were not found, but several small structures appearing to communicate with the main thoracic duct were ligated and divided. After decorticating the right lung, it was re-expanded in its entirety. The chest was then closed after a Bailey catheter was inserted through a stab wound in the ninth interspace.

Chest drainage during the first twenty-four hours after operation measured 350 c.c. of serosanguineous fluid, and after this time no drainage appeared. The chest catheter was removed after forty-eight hours and the convalescence was uneventful up to the time the patient was discharged on the thirteenth postoperative day. Chest films taken in the postoperative period showed progressive clearing of a small residual right pleural effusion, and six weeks postoperatively a chest film showed further diminution of the effusion, with a small residuum in the right costophrenic sinus and horizontal fissure. When seen at this time, the patient's cough had completely disappeared, as had her dyspnea and orthopnea. The physical examination was within normal limits except for the findings of a small amount of fluid at the right base posteriorly.

DISCUSSION

Chylothorax may be of traumatic or spontaneous origin. The literature is replete with reports of traumatic chylothorax,[5, 9] the reported trauma being minimal in many cases. The increased number of transthoracic surgical procedures involving dissection in and around the mediastinum has resulted in an increased incidence of trauma to the thoracic duct. Transthoracic sympathectomy has been associated with more injuries to the thoracic duct than any other intrathoracic procedure.[7] If trauma to the duct is recognized, ligation of the duct is a simple and effective means of preventing chylothorax. Reports of spontaneous chylothorax are much less frequent. The enthusiasm for prompt surgical treatment of this condition is not nearly as great as for traumatic chylothorax, since the underlying cause is frequently found to be a lymphoma, Hodgkin's disease, or carcinomatous invasion of the mediastinum. However, Klepser and Berry[8] emphasized the fact that these patients will tolerate ligation of the thoracic duct more readily than they will tolerate the inanition associated with continued loss of chyle. Furthermore, as in the case presented in this paper, occasionally no etiological factor will be found, and the prognosis should be good. Resectable lesions of the thoracic duct causing obstruction and rupture have been described.[10, 11]

In the absence of pleural effusion, the diagnosis of rupture of the thoracic duct is difficult to make. Following nonpenetrating trauma there is usually a latent period of several days, the average is four,[2-4] prior to the occurrence of a pleural effusion. The explanation for the latent phase is that there are two points of rupture, the first one in the thoracic duct and the second one, occurring at a later time, in the mediastinal pleura, usually in the lateral pulmonary ligament.[8] In cases of spontaneous chylothorax, events are similar: first, a rupture of the duct with leakage into the mediastinum, followed by secondary rupture of the mediastinal pleura with chylothorax. Stranahan[12] feels that chylothorax

secondary to a malignancy does not necessarily indicate rupture of the thoracic duct, but probably results from pleural weeping of chyle. On the other hand, Meade and his associates[5, 13] believe that a tumor must invade the duct, and that fixation of the duct with subsequent tearing during hyperextension then produces rupture.

In the case presented in this paper, the first manifestation of thoracic duct rupture clinically was the sudden appearance of copious sputum which had the gross characteristics of chyle. Although the diagnosis of bronchpleural fistula with expectoration of chyle is speculative, events indicate that instead of secondary rupture into the pleural cavity, secondary rupture was into the pulmonary parenchyma. Subsequent rupture into the pleural cavity led to closure of the bronchopleural fistula, and the distressing clinical manifestations of a rapidly reaccumulating pleural effusion.

The diagnosis of chylothorax should at once be suspected if the pleural aspirate has a milky appearance. There are numerous chemical determinations which will give positive identification of chyle. These tests can be found in any standard textbook of biochemistry and will not be discussed here. In every respect, the pleural aspirate in our patient was compatible with chyle. The use of lipophilic dyes such as D. and C. green No. 6 is an excellent method of determining not only the presence of chyle, but also persistence of its leakage.[7, 8]

Prior to Lampson's report,[1] the management for both the traumatic and nontraumatic cases was almost wholly supportive, with a high mortality. In at least 50 per cent of the cases, the chylous leaks failed to seal off and the patients died of inanition. The present nonoperative management of this condition should consist of a brief, but intensive trial of medical therapy, including repeated thoracenteses to permit complete expansion of the affected lung and apposition of the parietal and visceral pleura,[9, 14] and to relieve the marked dyspnea which invariably occurs as fluid accumulates. Closed thoracotomy drainage obviates the need for frequent thoracenteses and hastens the formation of an obliterative pleuritis. The diet should be one high in protein, high in carbohydrate, and low in fat. Chylous leakages entail protein losses of approximately 4.5 Gm. per hundred cubic centimeters. Supplements of intravenous human serum albumin should be given when oral feedings of protein have been inadequate. Low fat diet serves to decrease the flow of chyle, thereby encouraging closure of the opening, and also permits more ample protein and carbohydrate intake. Other supportive measures consist of treatment of the underlying disease and the prevention of infection. Since chyle has a marked bacteriostatic effect, infection is not likely to follow repeated thoracenteses. We feel that this nonoperative treatment should not exceed a period of two weeks, since the continued loss of chyle with its associated depletion of protein and general nutrition worsens the prognosis. Maloney's[14] successful nonoperative management of 21 cases of traumatic chylothorax suggests that immediate surgery is not warranted, but if leakage of chyle continues after the trial period, surgery should be performed.

The numerous reports in the literature of successful treatment of chylothorax by simple ligation of the thoracic duct in its lowermost portion attest

to the efficacy of this simple surgical procedure. Ehrenhaft and Meyers[15] showed that following ligation of the thoracic duct there were no demonstrable nutritional disturbances, and that the blood fat levels decreased immediately, but returned to normal within two or three weeks. Lee's[16] demonstration of the collateral channels developing after ligation of the thoracic duct explains the return to normal of the decreased blood fat levels and the lymphocyte count. That complete blockage of the lymphatic system is difficult to achieve is shown by Blalock's[17] ability to obtain complete blockage of the lymphatic system in only three dogs after 267 operative attempts. Klepser[8] ligated 18 normal thoracic ducts during thoracotomy for unresectable carcinomas and no adverse effects were noted. Anastomosis of the thoracic duct to the azygous vein as advocated by Hodge and Bridges[18] is time consuming and unnecessary. Seaman's[9] search for a method which would spare the thoracic duct is unwarranted and his ligation of an inverted pleural cone fashioned about the hole in the duct is unnecessarily elaborate.

The approach to the thoracic duct through a right thoracotomy incision was a satisfactory one in our patient. Even in the case of a left chylothorax, exploration through the right chest is preferable if the left lung is re-expansible.[13, 19] If the duct is to be approached from the left side, anterior retraction of the aorta after division of two pairs of intercostals is usually necessary. The advantage of approaching the thoracic duct through the involved pleural cavity is that decortication can be carried out at the time of thoracic duct ligation.

The identification of the thoracic duct at the time of surgery may be difficult. Lipophilic dyes[8] mixed with fatty substances injected into the stomach prior to surgery may help not only to color the duct but to distend it with chyle. The use of Evans Blue dye injected subcutaneously at the time of surgery has been advocated.[20] In our case, neither the injection of the dye mixed with oil and cream four hours prior to surgery, nor the subcutaneous injection of Evans Blue helped to identify the duct. After the duct is delineated it is important to look for collateral ducts. By employing x-ray visualization on the operating table, Stranahan[12] demonstrated a double channel in the lower third of the thoracic duct system in approximately 30 per cent of cases.

There have been few reports of technical difficulties encountered after the ligation of the duct. Whitcomb and Scoville[21] used a silver clip to occlude the proximal duct after its accidental injury during sympathectomy. The patient was well until the seventh postoperative day when chylothorax suddenly appeared. They postulated necrosis at the site of the clip or disengagement of the clip. In the case presented, the increased seepage of chyle around the most caudad silk tie, as the thoracic duct distended, suggested that the tie had cut through the delicate duct and permitted leakage. Religation with umbilical tape, even in the face of duct distention, stopped the seepage. The use of a broad flat ligature to occlude a distensible structure is a principle which has been used in vena caval ligation and may well be applied to thoracic duct ligation.

At the time of surgery, a point of leakage may occasionally be found in the mediastinal pleura which can be closed and tamponaded. Schumacker's[6]

successful control of 2 cases of traumatic chylothorax by closure of the pleural defect suggests the efficacy of this procedure. This method of control can be simulated nonoperatively by creating an obliterative pleuritis using 66 per cent glucose as suggested by Mills.[22] By either of these methods, however, the hole in the duct is patent, and if the mediastinal pleura ruptures at some other point, a recurrence of the chylothorax will ensue.

Search for the cause of spontaneous chylothorax at the time of thoracic duct ligation may disclose a resectable lesion. If a nonresectable lesion is encountered, biopsy and tissue diagnosis will enable the surgeon to treat the underlying disease more intelligently.

SUMMARY

1. An unusual case of spontaneous chylothorax with clinical manifestations of bronchopleural fistula has been reported.

2. The etiology, diagnosis, and management of chylothorax is discussed.

The authors wish to express their indebtedness to Dr. Nancy Davis for her invaluable help in the initial management of this case.

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TRACHEAL ATRESIA ASSOCIATED WITH TRACHEO-ESOPHAGEAL FISTULA

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INTRODUCTION

CONGENITAL tracheoesophageal malformations, usually in the form of a fistula with associated esophageal atresia, have been frequently reported in the literature. The first such instance was described by Richter in 1792.[1] Atresias of the respiratory tree, on the other hand, are a much rarer condition. In 1944, Montandon reviewed 11 cases of congenital stenosis of the trachea or larynx and reported an additional one.[2] Complete obstruction or atresia of the respiratory tree, however, is extremely rare. Payne reported the first one in 1900.[3] Search of the literature revealed only 4 cases in which there was complete absence of the trachea. Because of the rarity of this condition it is felt that the present case is worth reporting.

CASE REPORT

A white male infant was born at Hartford Hospital on Aug. 24, 1955. The mother was a 32-year-old white gravida iii, para ii whose estimated day of confinement was Aug. 12, 1955. The prenatal course was uneventful. She was Rh positive and had a negative serology. During the fourth month of this pregnancy, her other children had developed a transient rash of one day's duration. She, however, was asymptomatic.

The infant was delivered with low forceps under cyclopropane anesthesia following three hours of normal active labor. At birth the infant was pale, limp, with only sporadic forced respiratory gasps. Tracheal intubation was attempted but the tracheal tube could not be inserted. The baby continued to gasp, developed bradycardia, and failed to respond in spite of oxygen, high humidity, and stimulants. He died two hours and twenty-three minutes following birth.

Pathologic Examination.—The body was that of a well-developed white newborn male weighing 3,160 Gm., measuring 61 cm. in crown-heel length, and showing no anomalies on external examination. The pleural and peritoneal cavities were normal with the viscera in their normal relationship. The heart weighed 23 Gm. and showed no congenital abnormalities. A physiologically patent foramen ovale was noted. All major blood vessels were traced and found to reveal no anomalies. Ductus arteriosus was prominent and slightly larger than the arch of the aorta. The lungs, larynx, trachea, and esophagus were dissected together. Examination of the larynx showed a normal laryngeal cavity with a well-developed glottis and vocal cords. The laryngeal cavity was completely closed at its inferior margin below the vocal cords. The lungs and bronchi were well formed and the

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right and left main bronchi were joined by a normal carina which was closed off superiorly by a firm cartilaginous nodule, 8 mm. in diameter. There was a complete absence of the trachea or any vestiges of its between these two blind ends (Fig. 1).

The esophagus arose from the hypopharynx, was of normal diameter throughout, and joined the stomach in the normal fashion. At the level of the carina there was a 4 mm. fistulous communication between the lumen of the esophagus and the junction of the two bronchi. The only entrance of air to the lungs was through this fistulous communication. Along the surface of the esophagus, between the larynx and the carina, there were no cartilaginous or fibrous tissue remnants that would indicate tracheal vestiges. The bronchi contained a large amount of mucus and the lungs were congested and poorly expanded. Microscopically the lungs were well formed. They showed congestion of blood vessels and a moderate amount of atelectasis. Examination of the remainder of viscera revealed a 3 by 0.5 cm. Meckel's diverticulum but no other abnormalities.

Fig. 1.—Esophageal view of tracheoesophageal fistula. The termination of the trachea is seen as a blind stump joined to the partially visible left main bronchus. The right main bronchus is obscured by the esophagus and tracheoesophageal fistula.

DISCUSSION

Cases of complete obstruction of the respiratory tree are frequently associated with a tracheoesophageal fistula. As is seen in Table I, one half of the cases had such communication. In five of the 7 cases, there was complete absence of trachea. In one case, however, there was a complete functional obstruction of the trachea at its superior portion, but on closer examination a very small opening, 1 mm. in diameter, could be made out. There also was one instance of absence of larynx and the upper portion of trachea.

According to Arey,[10] the respiratory tract develops as an outpouching from the primitive foregut at the 3 to 4 mm. stage of the development of the embryo.

TABLE I. REVIEW OF TRACHEAL ATRESIA

AUTHOR	YEAR	LARYNX	TRACHEA	ESOPHAGUS	LUNGS
Fritz[4]	1933	Absent	Partial absence	Fistula to lower part of trachea	Normal
Potter[6]	1941	Normal	Closed with 1 mm. opening	Normal	Normal
Payne[3]	1900	Normal	Absent	Normal	Normal
Milles[7]	1950	Normal	Absent	Normal	Normal
Marek[5]	1940	Normal	Absent	Fistula to main bronchi	Normal
Kessel[8]	1953	Normal	Absent	Fistula to main bronchi	Normal
Present case	1955	Normal	Absent	Fistula to main bronchi	Normal

This pouch grows ventrad, caudad, and later divides into each lung bud. Further subdivisions form small bronchi, bronchioles, and the alveolar spaces.

Various theories have been postulated concerning the formation of tracheoesophageal fistula and associated abnormalities.[11] Keith and Spicer feel that the fistula results from an incomplete lateral fusion of the tracheoesophageal grooves which form a septum between trachea and esophagus.[11] Fluss and Poppen,[12] on the other hand, feel that the esophageal atresia and tracheoesophageal anomalies occur in association with the presence of anomalous blood vessels. Gruenwald states that the atresia of the esophagus occurs when the laryngotracheal tube, which is the site of the outpouching, fails to separate in the proper time sequence from the esophagus, so that the rapid growth of the trachea caudad stretches out the common portion and incorporates esophagus into trachea at that point.[13]

Along the same line of reasoning it is possible that in the "stretching out" process, the trachea becomes eliminated and the common portion becomes esophagus. We may wonder why esophageal atresia is so much more common than absence of the trachea. Embryologically the original outpouching of the future respiratory tract comes from the primitive foregut, and then differentiates into the larynx, trachea, bronchi, and the lung tissue. It may be that the onset of the differentiation takes place after this failure of the future trachea to separate from the foregut tissue. In such a case when the differentiation takes place all of the "common portion" becomes organized into the trachea causing absence of a portion of the esophagus. The few cases of tracheal atresia may be the rare instances where the differentiation toward the trachea in the "common portion" was absent or prevented because of some unknown factor.

SUMMARY

1. A case of tracheal atresia associated with tracheoesophageal fistula is presented with a brief review of similar cases from the literature.

2. It is to be noted that atresia of the trachea is extremely rare in comparison to that of the esophagus.

3. Congenital anomalies of the trachea and esophagus have been of renewed interest in recent years because of improved surgical techniques. It is felt that the recording of all unusual variants encountered may be of value to facilitate diagnosis, even though cases such as the anomaly presented have never been treated surgically.

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PRIMARY GRANULAR-CELL MYOBLASTOMA OF THE BRONCHUS

Report of a Case With Resection

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GRANULAR-CELL myoblastoma has been reported with increasing frequency in recent years. The greatest incidence of the tumor appears to be in the upper respiratory and digestive tracts. In 1949, Murphy, Dockerty, and Broders[6] pointed out that of the 229 acceptable reported cases, only 3 (1.3 per cent) occurred below the larynx. (1) Frenckner[2] (1938) reported a tumor in the upper trachea which had been successfully excised through a tracheostomy incision. Primary closure was successful and there was no recurrence. (2) Kramer[4] (1939) removed a myoblastoma of the right lower lobe bronchus in a 15-year-old girl. He used the punch and cautery method through a bronchoscope. (3) Horn and Stout[3] (1943) described tumor in the trachea. In 1952, Liebow[5] listed a primary myoblastoma of the left upper lobe bronchus in a Negro man, aged 59.

The following report concerns, we believe, the first patient with this type of tumor to be treated by lobectomy. It constitutes the third instance on record of a primary myoblastoma of the bronchus.

CASE REPORT

Mrs. E. H., a 36-year-old white housewife, was referred by Dr. Jane Paxson and admitted to the Samuel Merritt Hospital on June 26, 1954. The chief complaints were pain in the left chest, wheezing, and fever. Ten days prior to entry she developed moderate pain on inspiration in the left anterior chest, noted wheezing in the same area, and ran a low-grade fever. Localized wheezing was new to the patient, although she had had a chronic nonproductive cough with occasional generalized wheezing for many years. She smoked one package of cigarettes daily. Her past history was negative except for the removal of a benign breast mass two years previously. She denied food or pollen allergies in spite of the history of wheezing.

A routine minifilm taken two years before the present illness was reported as normal, but one taken six weeks prior to entry revealed a lesion in the left upper lung field.

Physical examination revealed a thin, white woman with a blood pressure of 122/78 mm. Hg, respirations 20, and pulse 72. She did not appear ill. The slightly enlarged thyroid was without discrete nodules. A constant inspiratory wheeze was best heard anteriorly over the left upper lobe. Occasionally there were expiratory rhonchi. The heart was normal.

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The hemoglobin was 14.2 Gm. per milliliter, and the red count was 4.1 million. The white count was 10,900 with 80 per cent neutrophils, 18 per cent lymphocytes, and 2 per cent monocytes. The urine was negative. The sputum showed no acid-fast bacilli.

Thoracic roentgenograms (Fig. 1) revealed infiltration in the left upper lobe. The findings were interpreted as atelectasis of the anterior segment.

Bronchoscopy was performed on June 26, 1954 (P. C. S.). Slight induration was noted around the orifice of the left upper lobe bronchus and there were minimal secretions. The orifices of both upper and lower divisions could be visualized through the right-angle telescope. The lower division was subtotally occluded by a pinkish-gray, irregular, slightly pedicled mass. It was pale, and edematous and suggested neoplasm rather than inflammatory tissue. The visible lumen of the lower division was 2 mm. in diameter. A biopsy was impossible due to the angle. The remainder of the bronchial tree was essentially normal. Papanicolaou's stains of the obtained secretions showed no tumor cells. On comparing bronchoscopy and roentgenograms, it was believed that the anterior segmental bronchus might be a branch of the lower division rather than of the upper division.

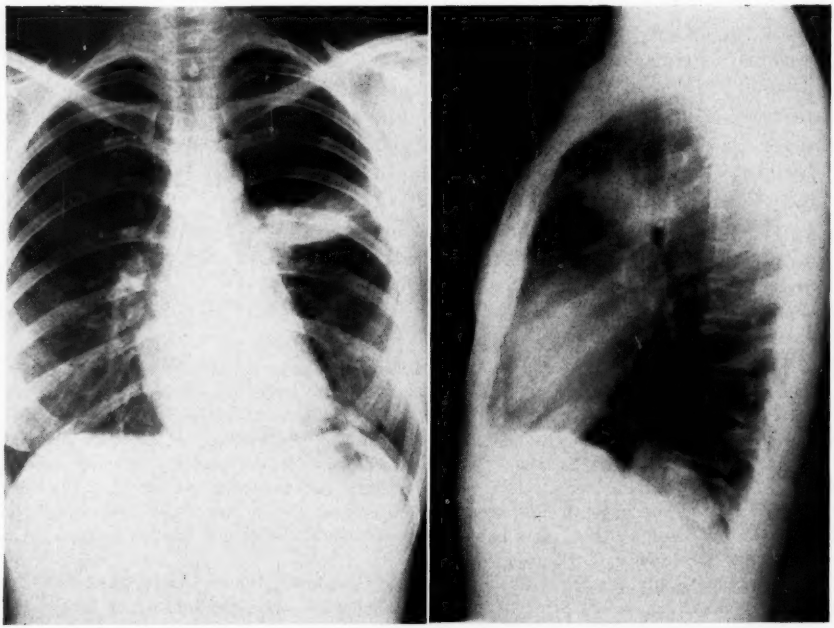

Fig. 1.—Roentgenograms of chest, frontal and left lateral views. There is an area of density with a sharply defined inferior margin and a less distinct upper border extending forward into the anterior segment of the left upper lobe. There is slight compensatory emphysema of the lingula.

On June 29, 1954, a left posterolateral thoracotomy was done and the left chest entered through the bed of the excised rib (P. C. S.). There were dense adhesions to the chest wall anteriorly and separation was partially in the extrapleural plane. A rubbery mass was palpated medially in the upper lobe, the hilar portion being more nodular. When the upper lobe was partially dissected out a generous biopsy was taken anteriorly; frozen sections showed this to be neoplastic, and probably a myoblastoma. A lobectomy

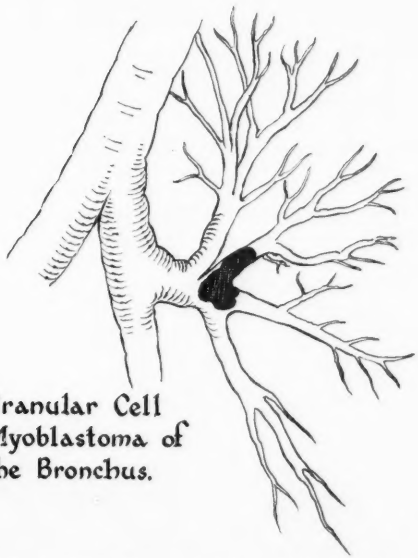

Fig. 2.—Semischematic drawing shows completely obstructed anterior segmental bronchus arising *with* the lower division of LUL. Thus the anterior segmental atelectasis and slight check valve emphysema of the lingula is explained. Apparently this is one variation of the trifurcate and according to Boyden has occurred in 10 per cent of his specimens.

Fig. 3.—Photograph of resected specimen looking end-on into LUL bronchus. The upper division is to the left. To the right of the main keel is the granular tumor mass, completely filling the anterior segmental portion of the trifurcate and partially obstructing the lower or lingular division. The latter can be seen just above the "54" on the identifying tag.

was therefore performed. Radical removal of all available lymph nodes and flush amputation of the upper lobe bronchus were accomplished. Two right-angled intercostal drainage tubes were used and the chest closed in layers using silk. The postoperative course was benign, and the patient was discharged on the ninth postoperative day.

Immediate examination of the resected specimen confirmed the impression that the anterior segmental bronchus arose with the lower division and was totally obstructed by neoplasm, while the lingula was partially blocked (Fig. 2). Pathologically there was a papillomatous lesion which extended into a peribronchial intrapulmonary lymph node as well as into the parenchyma of the lung for 1.8 cm. (Fig. 3). It was a light yellow-gray color and fairly well circumscribed. Distal to the obstruction in the anterior segment, there was a 2.5 cm. abscess with surrounding extensive consolidation.

The following microscopic description was made (R. H. S.): "Sections show squamous epithelium covering papillomatous intrabronchial projections. These are composed of large eosinophilic cells with small, round, central nuclei and abundant granular cytoplasm. [Fig. 4.] These cells penetrate between the bronchial cartilage plates into the peribronchial tissues and by direct extension involve a peribronchial intrapulmonary lymph node. Elsewhere there is extensive organizing pneumonitis with dense lymphocyte collections and there is also a subpleural collection of histiocytes beneath the fibrotic pleura. The diagnosis is granular cell myoblastoma of the bronchus with secondary obstructive pneumonitis and abscess."

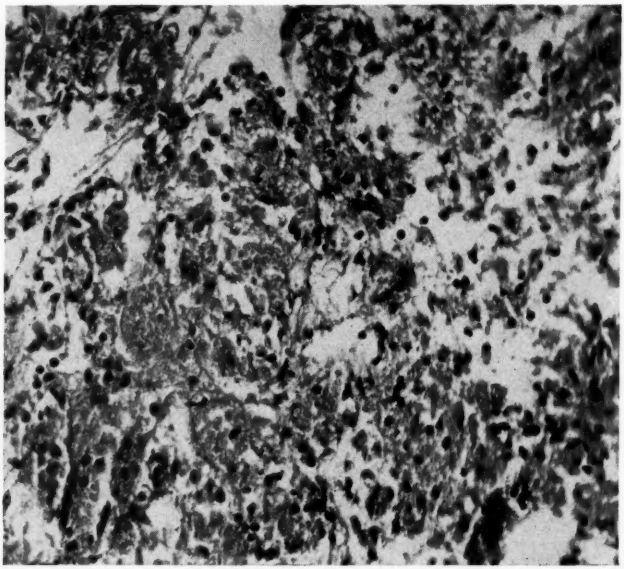

Fig. 4.—Photomicrograph; magnification ×270. (See text.)

SUMMARY

The patient-subject of this report is living and without symptoms or signs of recurrence thirty-four months following radical lobectomy for a granular-cell myoblastoma of the left upper lobe bronchus. This is the first recorded case of lobectomy for this type of neoplasm and is the third reported instance of myoblastoma occurring in the bronchus. While it is considered a benign

tumor in general, there are no criteria on which to base a judgment of relative malignancy or benignancy as far as origin in a bronchus is concerned. In the present case, it was proved on examination to be at least locally invasive. Necessarily, therefore, prolonged observation is in order in an effort to answer this question.

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LEFT HEART CATHETERIZATION

An Evaluation of Its Clinical Application in 450 Cases

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INTRODUCTION

LEFT heart catheterization has fulfilled a need for a more precise method of evaluation of cardiac hemodynamics, especially with respect to abnormalities of mitral and aortic valve function. Since its introduction more than two years ago, it has been utilized in many centers for the study of acquired heart disease. Although Facquet[1] and Allison[2] and their co-workers introduced measurement of the left atrial pressure by the bronchoscopic route, this technique has not provided a satisfactory method of left heart catheterization. The technique of transthoracic atrial puncture and catheterization introduced by Björk[3] and by Kent and associates[4] has been well accepted. However, the indications for patient selection and the complications which may be encountered have not been well documented in the literature. A presentation of our experience with 450 cases of left heart catheterization seems timely.

METHOD OF STUDY AND PATIENT SELECTION

The technique of catheterization in these patients has been reported in a previous publication.[5] A special needle, which enables simultaneous pressure recordings from the left atrium and ventricle, is employed at the present time. This was suggested by Wood and co-workers,[6] and is proving a useful method for recording pressure curves from these chambers simultaneously. Formerly, this could be accomplished only by inserting two needles into the left atrium.

The cardiac output is determined by the direct Fick principle, employing right heart catheterization simultaneously. The functional valve size then is calculated by employing a modification of the Gorlin formula.[7] This technique provides a method for assessing the dynamic significance of an obstructive lesion.[8] When the catheter does not pass into the aorta through the aortic valve, retrograde passage of a catheter may be done through the

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brachial artery. The central aortic pressure curve then is recorded simultaneously with the left ventricular pressure tracing to determine the presence and severity of the aortic valvular gradient.

Early in our experience, patients were selected for left heart catheterization if they were thought to have left-sided valvular lesions which might require surgical correction. The physiologic studies obtained have been reported in previous publications.[8, 9] As experience was gained, it became apparent that this study method had little to offer in purely or predominantly regurgitant lesions. Although patients with mitral regurgitation exhibited large "C-V" waves in the left atrial pressure tracing and evidence of whipping of the catheter back into the atrium with each systole, this information added little to the clinical evaluation. There appears to be no correlation between the severity of the regurgitant leak, as estimated at the time of surgery, and the height of the "C-V" wave or any other physiologic aberration in the left atrial pressure tracing. Likewise, in aortic insufficiency, the left ventricular pressure curve has no characteristics which aid in the quantitation of the regurgitant flow. Clinical appraisal and the level of the diastolic blood pressure, gross as they are, appear to give a more accurate picture of the significance of the aortic valvular incompetency.

INDICATIONS FOR LEFT HEART CATHETERIZATION

Left heart catheterization alone was done in 60 per cent of the patients, and a combined right and left heart catheterization in 40 per cent of the patients in this series. Combined heart catheterization has proved extremely useful in the evaluation of stenosis of the aortic or mitral valve. When there is a major degree of physiologic impedance to the forward flow of blood, the existence of a pressure gradient can be demonstrated across the involved valve with regularity. Since the measured gradient is a function of blood flow in relation to the size of a relatively fixed orifice, it became apparent early that the severity of the obstruction cannot be estimated accurately unless the cardiac output is measured simultaneously.

In clinically "pure" mitral stenosis, the use of this study method is not always considered to be necessary. If, however, a systolic murmur at the apex is associated, left heart catheterization may be employed in an effort to determine the significance of the stenotic component. The presence of a significant pressure gradient, particularly during late ventricular filling, would strongly favor predominant obstruction. Since the preferred approach in commissurotomy of the stenotic mitral valve now is through a right thoracic incision which precludes the possibility of any corrective surgical attack against mitral regurgitation, it becomes more imperative that associated regurgitation be recognized preoperatively. Left or combined catheterization is now used electively in this group of patients.

All patients considered clinically to have an aortic stenosis of physiologic significance are studied by combined heart catheterization. If signs of heart failure are evident, this study is preceded by a period of hospitalization and intensified medical therapy in an effort to restore the patient to a compensated

state. In those patients in whom aortic insufficiency is associated with the stenosis, left heart catheterization alone is preferred to the combined study. Preoperative evaluation of the severity of the stenosis is well correlated with the operative and autopsy findings.[8] In the absence of a transvalvular systolic gradient, aortic commissurotomy is not recommended. Postoperative studies in these cases of proved aortic stenosis have shown that simple dilatation of the aortic valve or a limited degree of commissural separation may be ineffective in reducing the pressure gradient.[10] A more complete reduction, but not always abolition, of the pressure gradient is obtained in these patients when a full tricommissural opening is accomplished by the surgeon.

In patients with both aortic and mitral stenosis, combined catheterization has been extremely useful in the preoperative evaluation of the obstruction at each valve. Frequently, these patients have shown a low cardiac output. Both the ventricular filling gradient at the mitral valve and the systolic gradient across the aortic valve are reduced. A severe physiologic obstruction, especially of the aortic valve, may be almost completely masked by the low rate of blood flow.

Clinical changes following mitral commissurotomy are often difficult to evaluate. Changes in cardiac output and in the level of pulmonary arterial pressure are inconstant following adequate surgery. Combined heart catheterization has been invaluable in assessing the surgical results.

Another indication for combined heart catheterization is the evaluation of recurrence of symptomatology suggestive of re-fusion of the mitral valve leaflets. Patients in whom stenosis of the mitral valve has recurred now may be diagnosed with clinical certainty by the demonstration of functional valvular obstruction. The failing myocardium and the regurgitant valve can be recognized more easily by exclusion of a significant stenotic element. Similar usefulness of this measure in the long-term evaluation of patients, who have been operated upon for aortic stenosis, is currently under way.

CONTRAINDICATIONS

Congestive heart failure has been considered a relative contraindication to left cardiac catheterization just as in the analogous study of the right heart. Certain associated diseased states might provide a suitable contraindication. Aneurysm of the arch of the aorta would be an example. Unsuitability of the patient for anesthesia or for corrective valvular surgery, should it be found necessary, may be considered as a proper reason for omitting catheterization. Emergency postcatheterization thoracotomy might be required in an occasional patient. Unsuitability for anesthesia, therefore, could result in a mortality.

COMPLICATIONS

The complications and their frequency are found in Table I. Staining of the pericardial fluid with small amounts of blood has occurred in nearly 75 per cent of the patients subsequently explored. This finding was not

TABLE I. TABULATION OF COMPLICATIONS: 450 CASES OF LEFT HEART CATHETERIZATION

COMPLICATIONS	NUMBER OF CASES	INCIDENCE PERCENTAGE
Hemopericardium	5	1.1
Hemothorax	20	4.4
Pneumothorax	10	2.2
Hemoptysis	12	2.2
Pyrogenic reaction	3	0.7
Acute bacterial endocarditis	1	0.2
Cerebral embolism	1	0.2
Catheter—cut off	2	0.4
Catheter—knot retained	5	1.1
Syncope and hypotension	3	0.7
Myocardial infarction, suspected (?)	1	0.2

associated with clinical symptoms or febrile reaction. Actual hemopericardium was diagnosed in 5 cases. Its presence was suspected in 3 patients because of a small pulse pressure and mild hypotension. These symptoms cleared without resort to pericardiocentesis. The existence of a hemopericardium, ranging in amount from 75 to 300 c.c., was identified in each patient at subsequent thoracotomy. In each, the source of the bleeding was believed to be a needle puncture of the base of the aorta.

Hemothorax occurred in 20 patients. In 18, one or more aspirations were required. The maximum amount of blood obtained on any single thoracentesis was 300 c.c. Complete radiographic clearing of the hemothorax was obtained in 19 of these patients; one patient required repeated aspirations for eleven days before complete expansion of the lung was obtained. One patient required a right thoracotomy twenty-four hours following catheterization because of hypotension and evidence of right hemothorax. This 43-year-old white female patient was being studied for possible valvular heart disease.[5] The data obtained from combined heart catheterization established the absence of any significant valvular pathology and indicated the presence of primary pulmonary hypertension. Emergency thoracotomy confirmed the presence of several hundred cubic centimeters of partially clotted blood within the right pleural space. An active bleeding point could not be demonstrated. Postoperatively, a continuous intravenous drip of norepinephrine (Levophed*) was required because of a persistent hypotension. The patient appeared to improve satisfactorily, but died suddenly four days later. Postmortem examination showed no positive findings except those vascular changes which are consistent with pulmonary hypertension. Patients with primary pulmonary hypertension are noted for the unpredictability of their course and for the circulatory "fragility" which they may exhibit.

A postcatheterization pneumothorax was recognized in 10 patients. In each, the lung collapse was estimated at less than 20 per cent. Prompt spontaneous re-expansion of the lung was noted in every case. Thoracentesis or catheter drainage of the pleural space was not required in any patient.

*Levophed bitartrate solution is available through the Winthrop Laboratories, New York City, N. Y.

Hemoptysis occurred in 12 patients. In each, this symptom subsided spontaneously. The one of longest duration persisted as blood-streaked sputum for six days postcatheterization. This complication appeared to be associated more frequently with a high point of entry of the needle into the left atrium.

Pyrogenic reactions were observed in 3 patients. They were treated with the usual antibiotic drugs. Antibiotics were not used during the early part of this series. However, because of the extended time which occasionally is required for combined heart catheterization, penicillin is now recommended prophylactically. This is given on the day of catheterization and on the succeeding day. One additional patient had a 3-day febrile illness following catheterization. This patient had aortic stenosis and had had a history of a previous prolonged febrile episode. Two weeks following the catheterization, the blood cultures were found to be positive for streptococcus viridans. She responded to antibiotic drugs administered over a 6-week period.

Short episodes of syncope have been observed in 3 patients. These were followed by hypotension, one patient requiring norepinephrine by continuous intravenous drip for a 24-hour period. The etiology of this untoward condition has not been determined. Air embolism secondary to needle puncture of the lung is suggested as a possible explanation.

In 2 patients, short sections of the polyethylene catheters were cut off within the left atrium by the beveled end of the needle during withdrawal of the catheter. Both of these patients were subjected to thoracotomy and mitral valve surgery within forty-eight hours. In one case, the severed section of the catheter was located within the atrium, while in the second it was found in the left ventricle. They were extracted without further difficulty. The indicated valvular surgery was carried out immediately.

In one of the patients reported in a previous publication,[5] a true knot became tied in the catheter during its intracardiac movements. This was removed by gentle traction. Since that report, in an additional 4 patients, knots have developed in the portion of the catheter which had been inserted within the left atrium. In each instance, when withdrawal has been found to be impossible, the catheter has been cut off flush with the skin. Thoracotomy was carried out on the following day, both to accomplish the corrective surgery and to remove the catheter. Three of these catheters were removed through the left auricular appendage, and one through the dissected interatrial groove at the time of right thoracotomy. One of these patients was a 72-year-old white man with severe calcific aortic stenosis. At the time of thoracotomy, aortic dilation was attempted, using the transventricular method. Because of the extremely heavy calcification and consequent rigidity of the tiny valve orifice, the usual dilating device could not be passed through the opening. The patient died twelve hours after thoracotomy due to hemorrhage from the ventricular incision. This death is not considered a result of the catheterization.

Sudden death, occurring in one patient, was attributed to cerebral embolization. This hypertensive patient was 43 years of age, was diagnosed as a case of recurrent mitral stenosis, and had a history of previous embolic episodes. Mitral commissurotomy had been performed three years previously. Because of recurrent symptoms of fatigue and dyspnea on exertion, she was being re-evaluated for possible re-fusion of the valve leaflets. Cardiac massage and other resuscitative measures failed. Post-mortem examination was not obtained.

One patient with a diagnosis of aortic stenosis developed severe and uncontrollable hypotension six hours after catheterization. The electrocardiographic evidence was inconclusive but suggestive of myocardial infarction. However, a diagnosis of pericardial tamponade was entertained. Accordingly, pericardiocentesis was performed to rule out the possibility of hemopericardium and pericardial tamponade. Sudden death followed. Immediate institution of cardiac massage failed to revive the patient. Post-mortem examination could not be obtained. Clinically, myocardial infarction seemed a probable cause of death.

The remaining late death was reported in a previous publication.[5] The post-mortem studies showed a far-advanced mitral regurgitation with detached chordae tendineae and a dilated mitral annulus. It is probable that the sudden death of this very ill patient within twenty-four hours of catheterization was purely coincidental.

DISCUSSION OF SURGICAL MANAGEMENT OF CERTAIN COMPLICATIONS

Hemopericardium, secondary to left heart catheterization, can be expected when the ascending aorta is punctured inadvertently. Thus far this complication has not produced cardiac tamponade, and it is believed that pericardiocentesis should be avoided whenever possible. The development of hemoptysis of partial pneumothorax requires no definitive treatment. Should tension pneumothorax develop, the usual decompressive measures would be in order. Hemothorax has occurred in 4.4 per cent of all the patients studied. Repeated thoracenteses are necessary in most cases with hemothorax. Thoracotomy should be avoided if possible since it may "tip the balance" unfavorably in a patient with a precarious tenure of life. It may have been the determinative factor in the patient with primary pulmonary hypertension.

Because of the small size and softness of the catheters, certain problems arise with their use. Rapid withdrawal should never be practiced. If the study must be terminated quickly, the needle should be withdrawn first. Then, the catheter may be removed without risk of amputating a segment within the atrial chamber. The possibility that the movement of the blood currents might tie the catheter into a knot may be avoided by passing only 8 to 10 cm. of the catheter beyond the needle tip. This usually provides adequate length for passage of the catheter into the ventricle. A simple loop knot in the catheter may be pulled out through the skin. If this fails, the catheter should be stretched, cut off flush with the skin, and allowed to

retract into the subcutaneous tissue. Subsequent thoracotomy then is required for its removal from the heart. If intracardiac surgery is necessary for the pre-existing pathology, no harm will be done by the simple additional maneuvers required for its removal.

SUMMARY

The indications and usefulness of left heart catheterization as a diagnostic method are evaluated. Our personal experience with 450 consecutive left-sided catheterizations is reported with a detailed review of the complications.

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Announcements

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Notice of Annual Meeting

The Thirty-eighth Annual Meeting of the American Association for Thoracic Surgery will be held May 16, 17, and 18, 1958, in Boston, Massachusetts. Headquarters will be at the Hotel Statler.

Requests for Hotel Reservations

These should be mailed directly to Mr. F. Whitehouse, Front Office Manager, Hotel Statler, Park Square, Boston, Massachusetts. Please mention this Association, the type of accommodation desired, the date, and approximate hour of arrival and departure. If accommodations are desired elsewhere in Boston, please communicate directly with the hotel of your choice.

Thoracic Surgery Forum

The Thoracic Surgery Forum will be continued as a special session at the 1958 meeting. The Forum is primarily for the presentation of short papers on current thoracic research, experimental problems, anatomical studies, and modified or new surgical techniques. The inclusion of any considerable amount of clinical material in these reports makes them unsuited for this session.

Papers at this session will be limited to ten minutes, including the showing of lantern slides or other illustrative material. At the discretion of the President, three minutes may be allowed as the maximum discussion for each paper.

All Thoracic Surgery Forum papers will be published together in one issue of the JOURNAL. Maximum length: 3,000 words without illustrations. If illustrated, an appropriate number of words must be subtracted for each cut used.

Abstracts of Papers

Abstracts of all papers for presentation at the 1958 meeting must be received on or before Dec. 15, 1957, otherwise they will not be considered by the Program Committee.

Abstracts should be labeled "For Thoracic Surgery Forum," or "For Regular Program." They should contain from 200 to 250 words and accurately reflect the content of the completed paper.

Six, repeat, six clearly legible copies of *each* abstract must be sent to Miss Ada Hanvey, Administrative Assistant, The American Association for Thoracic Surgery, 600 South Kingshighway, St. Louis 10, Missouri.

Essayists selected for the program are reminded that papers presented at the meeting *must* be handed to the secretary immediately after their presentation. If they are not ready at that time there is a chance that they will not be published in THE JOURNAL OF THORACIC SURGERY.

Motion Picture Session

Provisions have been made to show a limited number of motion pictures to be selected on a competitive basis. *The films themselves,* together with descriptive material concerning length of presentation, etc., must be received by Dr. Karl P. Klassen, The Ohio State University, Columbus 10, Ohio, before Dec. 15, 1957.

It is planned to run the motion pictures in a smaller room at the same time as the scientific sessions. If the films are well labeled, it will not be necessary for the author to be present for comment.

Applications for Membership

Applications for Associate Membership in the Association must be received by the Membership Committee not later than Dec. 15, 1957, otherwise the application will be deferred for consideration until the 1959 meeting.

Applicants must be sponsored by three Active or Senior Members of the Association. In addition to the signatures on the application form, the sponsors will forward a *separate* letter concerning the applicant directly to:

Dr. Duane Carr
Chairman of the Membership Committee
899 Madison Avenue
Memphis, Tennessee

Sponsors are reminded that *new* letters of recommendation must be forwarded to the Membership Committee should their applicants be held over for reconsideration a *second year.* The new letters of recommendation should also be sent to Dr. Carr, the Chairman of the Membership Committee.